NORSK GEOLOGISK TIDSSKRIFT

UTGITT AV

NORSK GEOLOGISK FORENING

OSLO

MED STATSBIDRAG OG MED BIDRAG
FRA NORGES ALMENVITENSKAPELIGE FORSKNINGSRÅD

REDAKTØR:
NIELS-HENR. KOLDERUP

BIND 40 - 41

A/S John Griegs Boktrykkeri
Bergen 1960

INNHOLD

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X-RAY STUDY OF POTASH FELDSPAR OF THE CONTACT METAMORPHIC ZONES AT GJELLERÅSEN, OSLO

By

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Abstract: Potash feldspar fractions from the intrusives and country rocks at Gjelleråsen have been studied using X-ray powder method. The potash feldspars of the country rocks far away from the zone of intrusion are triclinic in character. Approaching the contact zones the disordering of the feldspars typically increases. This is indicated by the decrease in triclinicity values in the same direction. The increasing degree of disorder in potash feldspars has been shown to be resultant of heat transfer across contact zones.

Potash feldspar exists in two different stable modifications — the triclinic microcline and the monoclinic sanidine. They have differences in their symmetry relations, due to order — disorder relations of Si and Al atoms, the triclinic microcline having the highest degree of order (Barth, 1934). By thermal treatment microcline can be converted into a sanidine-like form (Spencer, 1937). The reverse case has not yet been observed in experiments. The X-ray diffraction patterns of triclinic and monoclinic potash feldspars are readily distinguishable (Mackenzie, 1955) and (Goldsmith and Laves, 1954 a). A number of reflections from the monoclinic structure are split up into doublets with significant separation in the pattern for the triclinic member. Goldsmith and Laves (1954 a) selected the 131 doublet separation as an indication of degree of disorder (triclinicity) in the potash feldspar. The triclinicity factor $\triangle$ has been defined by them as $\triangle = 12.5\ (d_{131} - d_{1\bar{3}1})$ giving a triclinicity value 1 to a microcline from Madagascar. The triclinicity of the monoclinic form (sanidine) is 0.

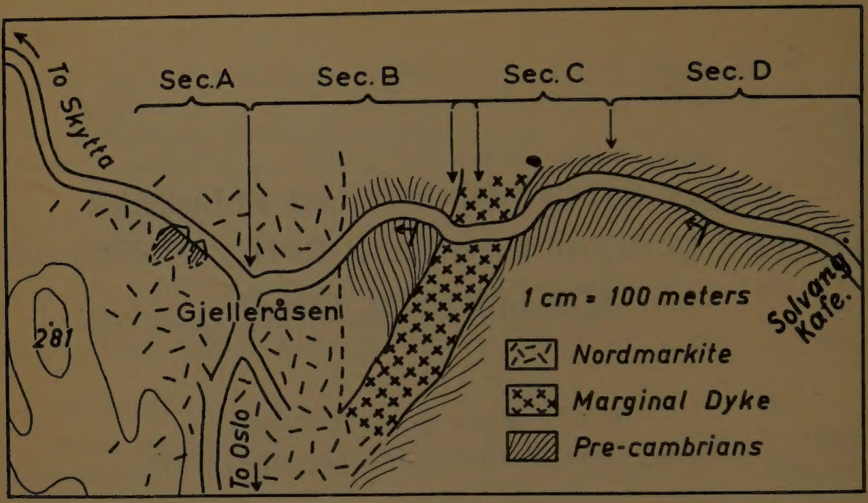

Fig. 1. Geological map of the area near Gjelleråsen.

Natural orthoclases and microclines give values of variable triclinicity. Goldsmith and Laves (1954 b) found that different regions of the same "crystal" often give rise to a large spectrum of triclinicity values. This induced them to state that the microcline-sanidine stability relations may not find a use in geologic thermometry in petrogenetic studies.

Goldsmith and Laves (1954 b) discussed the conditions under which intermediate structural series of potash feldspars can be produced. One of the possibilities being the metamorphic reheating of pre-existing potash feldspars which can be expected at a contact zone. Professor Barth suggested to me to take up the study of the potash feldspars of the contact zone near Gjelleråsen, Oslo, to find out whether or not the symmetry of the microcline of the pre-Cambrian rocks showed signs of any metamorphic reheating caused by the Permian intrusives.

Gjelleråsen is a small suburb 10 kilometres east of Oslo. In this region Permian nordmarkites have intruded the pre-Cambrian gneisses. Excellent contact zones are available for detailed study. The pre-Cambrian gneisses are heterogeneous in character, largely made up by quartzites, quartzitic rocks (with variation in amphibole, or mica, potash and soda feldspar with or without zoisite), augen gneisses, chloritic and micaceous schists, and amphibolite bands. On the northern side of Gjelleråsen, two xenoliths of pre-Cambrian rocks are seen along the road to Skytta and east of Gjelleråsen the main contact zone is exposed. There is a wedge-like mass of pre-Cambrian rocks in the eastern part of the Gjelleråsen area, sandwiched between the main nordmarkite mass and a connected porphyritic nordmarkite dyke.

A large number of specimens from the different parts of the contact zones were collected and the potash feldspars from them were carefully separated by gravity methods. Nonius Guinier camera was used and the spacings measured by a Hilger comparator. The accuracy of the $\triangle$ values determined does not exceed $\pm$ 0.02. To avoid criticism, that a selected fraction from a mineral separation by gravity methods would induce a bias to these measurements; the powder patterns of three fractions of feldspar from the same sample containing different amounts of plagioclase as an impurity (this would not affect the triclinicity value) were examined. The triclinicity values were found to be identical in all the three fractions. Thus, it is reasonable to assume that the average triclinicity value of potash feldspar in the lighter fractions containing the major amount of potash feldspar present in a sample is representative of the sample as a whole.

Since the Nonious camera has four slits, four powder patterns can be taken at the same time and the patterns can be studied in a relative way. In some cases the patterns of feldspars from rocks taken at increasing distance from the contact show only gradational changes in the "clearness" of the doublet. In all the cases the triclinicity value has been expressed in terms of the width of 131 doublet. Where the feldspar pattern consists of only a doublet, it is easy to correlate the triclinicity value with the degree of disorder. But in case of those feldspars which contain not only a doublet but also a sanidine phase in addition, the triclinicity values indicate the minimum disorder of the feldspars. It is not yet found possible to correlate the intensity of the sanidine peak with the degree of disorder (average). In all these cases the degree of average disorder is higher than is stated in terms of triclinicity value.

Experimental data.

In Table I triclinicity values of potash feldspars from the largest pre-Cambrian xenolith are given. The specimens are given in a serial order from the southern to the northern margins. The distances indicate the nearest distance between the contact and the sample locality.

The data suggest that feldspars close to the contacts are most disordered. A fuzzy 131 doublet with a central sanidine line is characteristic of feldspars at some distance from the contact.

The triclinicity values of two feldspars from the smaller inclusion (Fig. 1) were also determined.

Table I. Potash feldspars from large pre-Cambrian xenolith.

Specimen No.	Distance from contact (in metres)	Δ Value	Character of 131 doublet	Presence and character of sanidine line	Remarks
6	1	0.42	Fuzzy	Clearly visible	Doublet narrow in comparison to other specimens from the interior part of the xenolith.
3	5	0.46	Not clear	Strong line present	
2	9	0.74	Fuzzy	Sanidine line is very clearly present	131 doublet distinctly wider than specimen No. 6.
4	9	0.74 Approx.	Margins not clear	Sanidine line present	
1	9	0.66 Approx.	Not very clear	Not clear	
	Specimen very near contact (northern)	0.10 Approx.	Doublet very close to each other and fuzzy		

Specimen No. 8 (near contact): The doublet is not very clear and in between them is a strong sanidine line, $\triangle = 0.56$.

Specimen No. 9 (one metre away from the contact): The doublet is not sharp and the sanidine line is very weak, $\triangle = 0.66$.

In Table II triclinicities are given for potash feldspars from thermally affected pre-Cambrian country rocks sandwiched between the main nordmarkite and the marginal dyke.

Specimen Nos. are cited serially from the western part of the road section (nearer to Gjelleråsen) towards east. The data are somewhat puzzling. As regards the low $\triangle$ of the feldspar no. 63 the distance to the contact given in Table II for this specimen may far exceed the unobservable distance to the nordmarkite below (or above). The sanidine-like structural pattern may be due to the possible heating from underneath rather than from the side.

The optical study confirms the above results in that the potash feldspars with small to zero triclinicities have a low optic axial angle. The examples cited from pre-Cambrian xenoliths and country rock indicate increased disordering of feldspars at the contact zones (v.i.) (see Heier, 1957).

Table II. Potash feldspars from thermally affected pre-Cambrian country rock.

Specimen No.	Distance from contact (in metres)	$\triangle$ Value	Character of 131 doublet	Presence and character of sanidine line	Remarks
44	near contact	0.69	Margins not clear	No sanidine line	For a contact this value is anomalous and this feldspar might have been introduced from nordmarkite
45	10	0.63	Not very sharp and is fuzzy	Prominent sanidine line	
46	50	0.73	Sharp doublet	No sanidine line	
63	35	0.05	Sharp single peak	Single sharp sanidine line	

Potash feldspars from unaffected pre-Cambrian rocks.

In order to find the variations in structural geometry of potash feldspars unaffected by the Permian intrusion, specimens have been collected at regular intervals along the road section from Gjelleråsen to Solvang Kafe. Optically these feldspars were always microclines with cross-hatching but the powder patterns in certain cases presented rather anomalous results. Ordered feldspars are typical from 40 to 50 metres from the contact at the eastern margin of the nordmarkite dyke. The triclinicity value of some selected feldspars from these rocks are given in Table No. III.

The values indicate that the pre-Cambrian gneisses contained originally microcline before the nordmarkite intrusion. During this intrusion, the potash feldspars near the contact zones were disordered to various degrees.

Potash feldspars in nordmarkites.

Triclinicity values of potash feldspars from the nordmarkite close to the contact are given in Table IV.

Nordmarkite from the northern margin of the larger inclusion has a $\triangle$ of 0.70 and another in between the inclusions, 0.61. In the former there is a strong sanidine peak and in the latter a faint sanidine peak.

The nordmarkite dyke feldspars near the eastern gneiss contact at Gjelleråsen were studied as well and the results given in Table V.

Feldspars from central portions of the nordmarkite dyke have been examined with the purpose of studying the variations in $\triangle$ from place to place and to see whether or not the feldspars at the central parts are more ordered than at the contact. The results are given in Table VI.

Feldspars of the major nordmarkite intrusion taken far away from the gneiss contact gave triclinicity values between 0.77 and 0.86 with clear doublets indicating highly ordered feldspars.

Conclusions.

From the survey of the structural patterns of potash feldspars of contact zones at Gjelleråsen it can be concluded that the pre-existing ordered potash feldspars gradually become more disordered

Table III. Potash feldspars from pre-Cambrian country rock thermally unaffected by the Permian intrusives.

Specimen No.	Distance from contact (in metres)	Δ Value	Character of 131 doublet	Presence and character of sanidine line	Remarks
26	100	0.91	Sharp and clear	No	111 doublet (MACKENZIE, 1955) is present with wide spacing difference
29	120	0.89	Sharp and clear	No	Microcline twinning seen in thin section
53	200	0.84	Clear	No	Microcline twinning seen in thin section
52	250	0.75	Doublet not clear. Some transitional states appear to persist	No	Not possible to state whether this fuzziness is due to local heating by a dyke
51	380	0.70	No clear pattern	No	Small amount present in rock. Cannot be purified. The value is approximate
49	550	0.94	Clear doublet	No	Microcline twinning seen in thin section
48	620	0.61	Not very sharp	Present	Sanidine line possibly due to metamorphic reheating. Shows few cross-hatched microcline grains

Table IV. Potash feldspars of nordmarkite close to contact.

Specimen No.	Distance from contact (in metres)	△ Value	Character of 131 doublet	Presence and character of sanidine line	Remarks
65	1	0.76	Bordes not quite sharp	No sanidine line	—
66	2	0.80	Borders fuzzy	Sanidine line present	Some of the grains are optically slightly triclinic
11	3	0.76	Borders are not sharp	No sanidine line	Optic axial angles show variation from grain to grain
67	3½	0.80	Borders are moderately sharp	No sanidine line	
70	4	0.89	Borders are moderately sharp	No sanidine line	

Table V. Feldspars from nordmarkite dyke close to the eastern contact.

Specimen No.	Distance from contact (in metres)	△ Value	Character of 131 doublet	Presence and character of the sanidine line
38a	Near contact	0.73	Doublet hazy	Presence of sanidine line indicated
39	½	0.76	Doublet hazy, more clear than specimen No. 38a	No sanidine line
40	½	0.76	Doublet hazy	No sanidine line
41	1	0.79	Doublet clear*	No sanidine line
42	1½	0.81	Doublet clear	No sanidine line

* All patterns are rather cloudy and this term is used in a relative way.

Table VI. Feldspars from nordmarkite dyke.

Specimen No.	Distance from contact (in metres)	Δ Value	Character of 131 doublet	Presence and character of sanidine line
37	25	0.81	Doublet very fuzzy	No sanidine line
59	60	0.81	Doublet very fuzzy	No sanidine line
35	60	0.81	Doublet less fuzzy(?)	No sanidine line
34	40	0.85	Doublet fuzzy	No sanidine line
57	25	0.81	Doublet less fuzzy	No sanidine line
30	Near contact	0.73	Doublet fuzzy	No sanidine line

on approaching the contact zones. This conversion can to some extent be traced on X-ray powder diagrams and must be caused by magmatic heat transfer from the Permian intrusives into the pre-Cambrian country gneiss.

The results of the study are graphically illustrated in Fig. 2. While the structural patterns indicate that sanidinisation takes place in the region, the way such transformation takes place is problematic.

Both in the nordmarkites and in the pre-Cambrian inclusions, the feldspars at the contact zones in general have the following characteristics:

At the contact zone: Narrow 131 doublet, prominent sanidine line.
Away from the
contact zone : Broad 131 doublet, weak or no sanidine line.

Intermediate types of patterns have been obtained for rocks that are at moderate distance from the contact.

The feldspar samples taken for X-ray work represent an assemblage of potash feldspar grains from a single specimen. It is possible that all the grains do not show the same triclinic character. If some grains

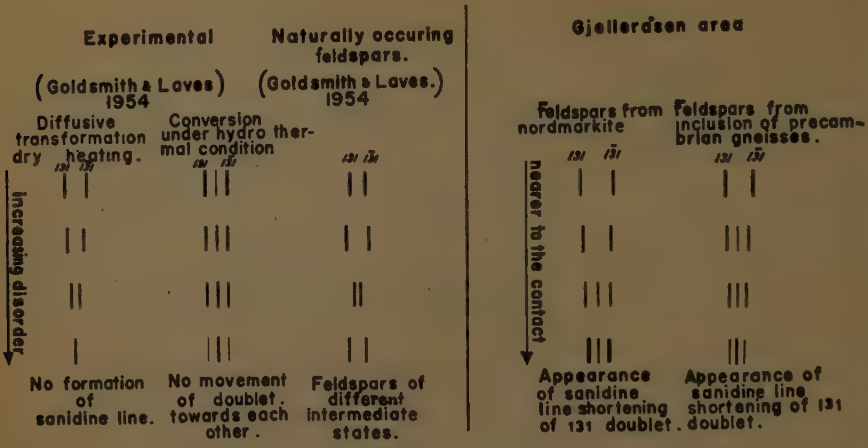
Experimental
Naturally occuring feldspars.
(Goldsmith & Laves) 1954
(Goldsmith & Laves.) 1954
Diffusive transformation dry heating.
Conversion under hydro thermal condition
131 1̄31
increasing disorder
No formation of sanidine line.
No movement of doublet. towards each other.
Feldspars of different intermediate states.
Gjellerdsen area
Feldspars from nordmarkite
Feldspars from inclusion of precambrian gneisses.
nearer to the contact
Appearance of sanidine line shortening of 131 doublet.
Appearance of sanidine line shortening of 131 doublet.

Fig. 2. Sanidine-microcline stability relations.

are triclinic and others monoclinic the patterns of the samples will be those obtained in this study.

The other possibility is that of the environment was neither dry nor completely wet so that both diffusive and conversion types of transformation took place. This would explain the appearance of a sanidine line together with the narrowing of the 131 doublet in the potash feldspars. It is also possible that this conversion is a type of diffusive transformation, with changes occurring rapidly so that intermediate states are not preserved.

The third possibility is to assume that this type of gradational patterns is in a way due to the influence of sodium content in the feldspars. It has been established that the 131 doublet is influenced by the sodium content in solid solution in the feldspar (RAO, unpublished). The reactions taking place in the laboratories and in nature may be different in that the experiments in the laboratories are conducted as "closed system" while this can hardly be expected in nature. When potash feldspars are heated by magmatic heat, not only do they undergo the low-high transformation but also convert themselves to alkali feldspars depending on the amount of Na diffusion possible from the surroundings.

To summarise, the gradational movement of the 131 doublet and the presence of a sanidine line is interpreted as due to either 1).

action of both diffusive and conversion types of transformation; 2). changing environmental conditions; 3). control of lattice structure by the presence of sodium in the potash feldspar. In a contact zone, all these factors may operate in a cumulative way.

The nordmarkite feldspar crystallized originally in the monoclinic form and the feldspars of the pre-Cambrian rocks were originally highly ordered microclines. The magmatic heat converted the feldspars close to the contact to a sanidine like form. During the declining phases of metamorphism, the feldspars underwent "reversion" to various degrees and the feldspars exhibit today gradational patterns dependent on the earlier metamorphic reheating and later "reversion".

Acknowledgements.

This forms a part of the work submitted for the Ph. D. degree of this Institute and was carried out at the Geologisk Museum, Oslo, Norway, to where, I was deputed for higher studies during 1956—57 by the Director of this Institute. The Royal Ministry of Foreign Affairs, Norway, awarded the scholarship and Ministry of Education, Government of India, paid my passage costs. I am highly indebted to the above authorities.

These studies have been made possible, by the constant help, guidance and criticism by Professor Dr. Tom. F. W. Barth, Director, Geologisk Museum, Oslo, whom I thank heartily. I am also highly indebted to the staff and research workers at the Geologisk Museum, Oslo. The diagrams have been drawn by Miss I. Lowzow and photographed by Miss B. Mauritz, whose help is hereby acknowledged. I also thank Dr. T. C. Bagchi, who has helped me in various ways in the pursuit of studies on mineralogy, from the time I joined this Institute.

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Manuscript received November 11, 1959.
Printed February 1960.

BANDED GNEISSES OF THE RANDESUND AREA, SOUTHEASTERN NORWAY

BY

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Abstract. Banded gneisses within the Randesund area, southeastern Norway show evidence of the control over their presently observable banding by original supracrustal stratification. Most of these banded gneisses appear to be essentially isochemically metamorphosed supracrustal rocks; some also exhibit the results of chiefly chemical metamorphic differentiation; some bands have undergone marked cataclasis; some bands contain potassium feldspar grains at least some of the constituents of which have moved into their present relative positions since the original supracrustal materials were deposited; and, some bands possibly have undergone at least partial anatexis and gained local mobility during their histories. Nearly all the gneisses show evidence of having undergone structural deformation with formation of features generally considered to represent "flow zone" conditions.

Especially noteworthy parts of this paper so far as general petrologic considerations are the discussion and partial checking of certain aspects of the validity of the BARTH two-feldspar geothermometer and the trace element analyses of amphibole-rich bands of the Randesund area gneisses. It is concluded that although certain aspects of the thermometer's validity need further checking that it is of great use so far as determining at least local relative temperatures at which equilibrium last existed between the feldspar phases. Also, trace element studies such as those made appear to offer a means of possibly determining origins of diverse amphibole-rich rocks within some given metamorphic facies of certain areas.

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Introduction

GENERAL STATEMENT

Many areas, especially of the southern Fennoscandian Precambrian Shield, have been mapped geologically as being underlain by "banded gneisses".[1] In accompanying texts the rocks have been termed not only banded gneisses but also such things as arterites, venites, phlebites, stromatites, veined gneisses, composite gneisses, mixed gneisses, permeation gneisses, injection gneisses, and banded migmatites.

Chiefly because some of these gneisses contain bands of granitic or near-granitic composition the rocks have gained prominence in the petrological literature concerned with the problems of how granites may be formed. This prominence has been both unwarranted and unwise because of the fact that none of these gneisses has been studied intensively in both the field and the laboratory by any one geologist. In an attempt to remedy this situation banded gneisses which are especially well exposed in the Randesund area of southern Norway were studied in detail both in the field and the laboratory.

ACKNOWLEDGMENTS

This investigation was carried on during the 1958—1959 academic year while I was in Norway under the auspices of the United States Educational Foundation in Norway (Fulbright Program). Field expenses in Norway were defrayed by Norges Geologiske Undersøkelse. Office and laboratory facilities were made available at the Mineralogisk-Geologisk Museum in Oslo. Professor T. F. W. BARTH of that museum suggested the Randesund area as a base area for the investigation, discussed many of the problems involved, and in many other ways aided me to carry on the study. Director HARALD BJØRLYKKE and former director SVEN FØYN of Norges Geologiske Undersøkelse were most helpful in preparing the way for my accomplishment of numerous field and laboratory tasks. Many other staff members of

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[1] Although band(ed, *etc.*) is a two-dimensional designation, banded gneiss is too ingrained in geological literature to be changed merely for the sake of etymological correctness. The form band to designate a "unit" of a banded gneiss is also used.

the museum and of the survey were most helpful. While in the Randesund area, the OLE K. RANDØYS of Kongshavn aided me in many ways.

It gives me a great deal of pleasure to acknowledge grateful thanks for all these contributions to the investigation.

MISCELLANY

Definitions subscribed to so far as this study of banded gneisses, criteria used to distinguish among possible modes of formation, and a review of some of the most important previous literature concerned with banded gneisses are given in another paper (DIETRICH, 1959c). The classification suggested in that paper is repeated below for easy reference:

- *Relict*
  - Igneous banding
    - flow
    - differentiation
    - segregation
  - Supracrustal stratification
- *Composite*
  - Migmatization
    - lit par lit injection
    - differential melting
  - Permeation
    - hydrothermal activity
    - pneumatolysis
    - molecular and ionic diffusion
- *Metamorphically Differentiated*
  - Mechanical redistribution
  - Chemical redistribution
- *Eclectic*
  - Combination processes.

Randesund area, southern Norway

GENERAL STATEMENT

The Randesund Area is located between Kristiansand and Lillesand in southeasternmost Norway. The most recent interpretation of the geologic setting of the area has been given by DIETRICH (1959a).

Briefly and incompletely, the interpretation is: the banded gneisses are part of the socalled Bamble formation, chiefly metamorphosed supracrustal rocks, of the southern Norway Precambrian "complex"; the gneisses are highly folded and locally are closely jointed; and, they comprise part of a large fault block the overall movement of which was such that the granitic gneisses — commonly referred to as granitized Telemark formation — which crop out northwest of the fault zone (*i.e.*, across Topdals River-Fjord from the Randesund Area) are possibly similar to the rocks that underlie the banded gneisses.

These and similar banded gneisses of southern Norway have been interpreted previously as injection gneisses (C. BUGGE, 1917, pp. 87—91; HOFSETH, 1942, p. 28; J. BUGGE, 1943, pp. 25—26; BARTH, 1945, pp. 3—7), "solid residues after a differential re-fusion with subsequent squeezing out of the pore liquor thus formed" (BARTH, 1933, pp. 308—309); the slightly to moderately granitized rocks of the border zone of a highly granitized zone (BARTH, 1947, pp. 9—10), gneisses the banding of which may represent primary stratification (J. BUGGE, 1943, p. 25), and gneisses the banding of which was formed as the result of metamorphic differentiation (J. BUGGE, 1943, pp. 27—36).

PETROGRAPHY

Although cursory examination of the Randesund Area banded gneisses could easily lead to the misconception that they consist of alternating granitic and amphibolic layers, actually they are comprised by many diverse lithologies which occur as alternating light and dark bands that range from a few grains to a few meters thick and up to 10's of meters in observable lateral extent. Lithological diversities and at least a suggestion of the range in band thicknesses are evident on Table I and Figures 3 and 4.

The section described was chosen because it was the best exposed, readily accessible, unweathered section within the area at the time of the field investigations. The pictured specimen and outcrop are typical of banding subject to photographic presentation. The relatively broader bands (Fig. 3) grade thicknesswise, upwards to individual units of general overall similar characters that may be indicated on relatively large scale maps — see, for examples, the meta-arkose and amphibole-rich foliate units on the BUGGE—DIETRICH map (DIETRICH, *op. cit.*, Figure 1). Some thin bands are literally a few mineral grains thick but, nonetheless, because even these bands are recognizably continuous over distances measurable in meters they constitute banded gneisses which are quite distinct from what are usually termed gneisses (unmodified). (see Fig. 4).

As is evident from the described section, some of the "bands" as listed actually consist of numerous thinner bands — in general, the description was framed so that band groups with overall similarities are listed as one band (*e.g.*, band no. 7 actually consists of 25—30 recognizable bands but all are similar and quite different megascopically from the overall lithologies of band units nos. 6 and 8).

Table 1.

Section (WNW to ESE) across banded gneiss exposed in the small roadside quarry and adjacent cuts on the north side of the road a few meters west of the bridge across Fidjekilen Fjord and approximately 4.5 km. S.70° E of Kristiansand. (Colors are those of Goddard *et al.* chart — 1948).

	Approximate thickness, cm	General Description
1)	7.5	medium dark gray biotitic feldspar-bearing actinolite-rich gneiss
2)	12.	grayish pink granitic gneiss with grayish black biotite-rich partings
3)	1.5	dark greenish gray chlorite-actinolite schist with central 4 mm pinkish gray granitic band
4)	2.	pinkish gray biotitic feldspar-bearing foliated quartzite
5)	1.5	grayish olive green schistose epidote-bearing chlorite schist with foliation at an angle to banding
6)	2.	pinkish gray magnetite-bearing feldspathic schistose quartzite
7)	13.	overall light brownish gray subvitreous conchoidal feldspathic quartzite with bands as thin as 1 mm marked by diverse relative concentrations of quartz, feldspar, and mafic minerals; most thin bands are grayish moderate orange pink and light gray
8)	5.	greenish black chlorite-bearing amphibolite
9)	16.	light gray and light brownish gray subvitreous conchoidal feldspathic quartzite similar to no. 7 but with two approximately 1 cm thick grayish to moderate orange pink feldspar-rich bands with biotite rich selvages (< 1 mm thick)
10)[1]	8.	light and pinkish gray subvitreous feldspar-bearing quartzite with several less than 1 mm thick discontinuous bands relatively rich in biotite and/or actinolite and sporadic muscovite
11)[1]	3.	dusky yellowish green epidote-rich quartzite with local lenses of moderate orange pink feldspar-rich quartzite

[1] Specimens chemically analyzed — see Table II.

12)[1]	8.	grayish black actinolite gneiss with sporadic 2—4 mm thick greenish black bands
13)	0.8	grayish olive green chlorite schist
14)	5.	pinkish gray to light brownish gray laminated subvitreous feldspar-bearing quartzite similar to no. 7.
15)	11.	dark gray quartzite with approximately 1 mm thick bands marked by abundant magnetite and/or other mafic minerals
16)	18.	overall pinkish gray feldspar-bearing foliated subvitreous gray feldspar-bearing foliated subvitreous quartzite with marked color banding (*e.g.* medium light to medium gray, grayish orange pink, light greenish gray, and greenish black), chiefly dependent upon diverse quartz-feldspar ratios; a few up to 5 mm thick pure colorless to smoky quartz bands
17)	17.	brownish gray, pinkish gray, and light greenish black banded subvitreous conchoidal feldspar-bearing quartzite with sporadic relict crossbedding
18)	12.	brownish gray subvitreous feldspar-bearing banded quartzite similar to no. 7 and with numerous 1—4 mm thick nearly pure feldspar bands
19)	7.	grayish black actinolite gneiss with central 2 mm thick quartz band
20)	3.5	pinkish gray granitic gneiss
21)	6.5	overall brownish gray vitreous conchoidal feldspar-bearing quartzite similar to no. 7 and marked color banding (*e.g.* orange pink, dark gray, grayish pink, and greenish gray) chiefly dependent upon diverse feldspar to quartz ratios; a few 1—2 mm thick nearly pure milky to smoky quartz bands
22)	6.	pinkish to light gray banded quartzite with approximately 1 mm thick bands rich in biotite and 3—7 mm thick bands rich in light pink-orange feldspar
23)	15.	medium light gray and light brownish gray subvitreous feldspar-bearing quartzite similar to no. 7
24)	2.5	greenish gray subvitreous epidote-bearing quartzite
25)	1.7	pinkish gray feldspar-bearing quartzite
26)	9.	dark greenish gray epidote- and amphibole-bearing banded quartzite
27)	3.	moderate pink feldspar-rich granitic gneiss
28)	2.3	medium dark gray biotite-chlorite-actinolite gneiss
29)	0.7	pinkish gray feldspar-bearing quartzite
30)	0.5	medium gray biotite-actinolite gneiss
31)	1.3	medium light gray feldspar-bearing quartzite
32)	2.	medium dark gray biotite-actinolite gneiss
33)	18.	moderate orange pink granitic gneiss with alternating 1—4 mm thick feldspar-rich and nearly pure milky quartz bands
34)	1.2	medium light gray biotite-bearing subvitreous quartzite
35)	0.8	medium dark gray biotite gneiss
36)	2.5	medium light gray feldspar-bearing gneissic quartzite with four less than 1 mm thick biotite-rich bands

[1] Specimens chemically analyzed — see Table II.

37)	1.8	grayish orange quartzite
38)	1.8	light greenish gray subvitreous quartzite
39)	3.	medium dark gray biotite gneiss
40)	0.5	medium light gray biotite-bearing quartzite
41)	0.3	medium dark gray biotite gneiss
42)	8.	light brownish gray subvitreous feldspar-bearing quartzite similar to no. 7 with two approximately 1.5 cm thick pinkish gray feldspar-rich bands
43)	6.5	medium dark to dark gray biotite-bearing amphibole schist
44)	0.8	light greenish gray quartzite
45)	0.6	medium dark gray biotite-bearing amphibole schist
46)	0.5	pinkish gray quartzite
47)	1.	medium dark gray biotite-bearing amphibole schist
48)	14.	grayish orange pink alaskitic gneiss with milky quartz lenses
49)	19.	streaked grayish pink and light greenish gray cataclastic granitic gneiss
50)	4.5	grayish pink alaskitic gneiss with some approximately 1 mm biotite- and quartz-rich bands
51)	7.5	pinkish gray and light brownish gray banded subvitreous feldspar-bearing quartzite similar to no. 7
52)[1]	2.5	light gray alaskitic gneiss with a few thin biotite-rich bands
53)[1]	3.	dark gray biotite-bearing amphibole gneiss
54)[1]	6.	moderate orange pink feldspar-rich granitic gneiss
55)	2.	pinkish gray granitic gneiss with sporadic dark green chlorite partings
56)	0.6	medium dark gray magnetitic biotite gneiss
57)	0.5	medium light gray feldspar-bearing quartzite
58)	0.2	medium dark gray biotite gneiss
59)	1.6	medium light gray banded quartzite
60)	1.8	medium dark gray biotite gneiss
61)	0.7	very light gray feldspar-bearing quartzite
62)	0.5	medium dark gray biotite gneiss
63)	0.3	light gray feldspar-bearing quartzite
64)	0.2	medium dark gray biotite gneiss
65)	0.1	light gray quartzite
66)	3.2	medium dark gray biotite gneiss
67)	1.4	light gray subvitreous quartzite
68)	4.5	medium dark gray biotite gneiss
69)	0.3	greenish gray chlorite-rich schist (parting?)
70)	3.5	nearly white cataclastic alaskitic gneiss with notable quartz leaves
71)	7.	very light to light gray biotite- and feldspar-bearing quartzite
72)	6.	grayish pink cataclastic alaskitic gneiss
73)	1.5	grayish olive green epidote-bearing chlorite schist
74)	6.	greenish black highly crenulated actinolite gneiss
75)	0.3	pinkish gray feldspar-bearing quartzite
76)	1.7	medium dark gray biotite gneiss

[1] Specimens chemically analyzed — see Table II.

Most of the megascopically visible features that appear to pertain to genetic considerations of the banding of the banded gneisses occur in the rocks of the described section: band to band thickness differences, diversity of composition (and even possibly metamorphic grade?) of spatially associated bands, concentrations of "heavy minerals" in lenses and along certain laminae parallel to the banding, relict cross-bedding (?), quartz-feldspar bands with biotite-rich selvages on both sides, apparently isolated cataclastic features, and schistocity (cleavage?) of a few bands at an angle to the main banding. Also most readily recognizable in the field are such gross features as: marble and quartzite "formations" concordantly interlayered with the banded gneisses, relict scour-and-fill (?), lenticular masses — especially of amphibole-rich foliates, an occurrence of ptygma, a few highly folded zones, sporadic flow structures, and numerous "dents de cheval" (porphyroblasts).

Most of the porphyroblasts are moderate to grayish orange pink microcline; a few also contain pale greenish yellow plagioclase and a couple were found to contain black yttrium-rich allanite (as cores surrounded by microcline). Some of the microcline ones are composed of one grain; some are comprised by finely granular aggregates. The single-grain ones are most plentiful and constitute essentially all of the large porphyroblasts. Although nearly all of these are lenticular in shape, locally — especially where they are present in relatively large concentrations — a few have nearly prismatic shapes. Individual porphyroblasts up to 35 cm in intermediate dimension have been observed to occur. Typically the shortest dimension of each porphyroblast is essentially perpendicular to the foliation of the enclosing rock. In general, *b* crystallographic axes of the microcline of the single-grain porphyroblasts are subnormal to the foliation; no other preferential crystallographic orientation has been recognized. Most of the porphyroblasts occur concentrated adjacent to certain bands — most commonmonly to biotite-rich ones; many exhibit no such relationship, however. Locally the porphyroblasts are aligned.

Thin section studies have, in addition to corroborating megascopic observations, added such pertinent petrographic data as the following (minus most fabric features which are given in the next section, Petrofabrics): All of the minerals of most bands and most of the minerals of other bands appear to have attained their present forms through recrystallization. Most of the quartz and much of the microcline and plagioclase exhibit undulatory extinction. The plagioclases ($An_{3 \text{ to } 28}$) are essentially unzoned. They are highly sericitized in some bands and quite fresh in others. Some of the microcline is microperthitic — in general, this quality is more apparent in large (augen) than in small (general mass) grains (in fact, some of the latter contain no recognizable plagioclase). Biotite, hornblende-actinolite, and (in a few bands) epidote are the chief mafic minerals in the gneisses. Most of the biotite grains have a preferred orientation with their main cleavage subparallel to the banding. Biotite with pleochroism of x-nearly colorless and y & z-dark green is most common but that with pleochroism of x-buff and y & z-dark brown also occurs. Locally the biotite (generally the green type) has undergone marked chloritization, in some cases apparently with accompanying formation of relatively minor amounts of muscovite. The amphibole is pleochroic in greens or in greens and light tan. It also has preferred orientation locally (prismatic cleavages subparallel to foliation) but nowhere so well developed as that of the biotite. All amphibole grains are irregularly shaped. Some, especially the large ones, are poikiloblastic. Epidote is the major mafic mineral of a few layers the parageneses of which are typically quartz and epidote nearly 100 per cent. Epidote family minerals also occur in accessory amounts in many other layers. At least three varieties have been recognized to occur — optically positive clinozoisite, optically negative and essentially nonpleochroic pistacite, and optically negative and markedly pleochroic (x-lemon yellow, y-greenish yellow, z-yellowish green) pistacite; more types may be separated on the basis of grain sizes, mineral associations, and presence versus absence of inclusions. Not uncommonly two varieties occur in the same and/or adjacent band(s). The other most common constituents are magnetite, sphene, zircon, and apatite. Magnetite occurs as both large grains probably formed (recrystallized?) within the rock and grains that have characteristics generally described as those of clastic grains. Some of the sphene occurs as well developed wedge-shaped crystals and most of it looks like it was formed *in situ;* it is commonly concentrated in the magnetite-rich zones. Many of the zircon grains are of typical clastic character; some appear to be "broken rounds". Grains of diverse varieties of zircon (on basis of color differences among similarly oriented grains) occur in some individual bands. The apatite is present as relatively large grains, *i.e.*, of about the same size as the quartz and feldspar grains. Typically the zircon, magnetite, sphene, and apatite occur concentrated in certain bands or small lenses. Calcite and myrmekite have been observed to occur in a few bands. In one section, the calcite appears probably to represent recrystallized sedimentary carbonate in that it constitutes a folded discontinuous layer which appears to have been folded and recrystallized before a partial reconstitution which, among other things, involved formation of actinolite hornblende (such features as needles of amphibole penetrating calcite occur). That some of this calcite is associated with epidote (of the marked pleochroic type) may be suggestive so far as the origin of at least some of the epidote of these gneisses. Also present in a few of the layers is an unindentified opaque material which occurs along grain boundaries of the chief minerals, quartz and feldspars, in the rock.

Examination of thinsections across layers with selvages along both their borders has shown that: the selvages are zones of relatively high biotite plus or minus magnetite and sphene contents; this biotite is typically chloritized and the responsible process(es) apparently also resulted in formation of minor amounts of muscovite; the biotite and chlorite grains are oriented preferentially with the main cleavage subparallel to the band contacts; and, compositionwise the selvaged central band is finer grained, more equigranular, lower in plagioclase content, and richer in magnetite than the bands outside the selvage zones.

It may be seen by examining thinsections that intersect boundary zones between "dents de cheval" and their surrounding rocks that these porphyroblasts have apparently exerted pressure on the minerals of the surrounding rock and in some cases possibly even to have promoted recrystallization of some of those minerals. Some of the porphyroblasts are essentially single grains, perthitic microcline; others consist of many extremely small grains of perthitic microcline with no apparent preferred orientation with respect to either the shape of the porphyroblastic unit or to each other. Quartz is also present in some of the porphyroblasts and in some of the large single-grain ones it occurs as relatively large grains with the whole then suggestive of what would be expected as intermediate between the pure feldspar porphyroblasts and small pegmatite lenses. At least some of the "single-grain porphyroblasts" contain a network of intersecting thin vein-like features constituted chiefly by fine-grained non-perthitic microcline plus or minus a few sporadic strained quartz grains, also of fine grain size. These, along with the porphyroblasts, themselves, appear to be evidence for at least two periods of movement of feldspar- (and quartz-?) depositing solutions.

Thinsections of pegmatite-banded gneiss "gradational" contacts and other zones that appear megascopically to have undergone feldspathization have proved to be of little aid. No means has been found to the present to distinguish feldspars of such zones from those of adjacent or nearby nonfeldspathized (at least not recognizable feldspathized) zones.

The cataclastic ("mylonitized") types examined in thinsections are remarkably similar to each other. They consist chiefly of highly sheared feldspar and completely recrystallized leaf quartz. Also characteristic of these is an extreme sericitization of the plagioclase. In two sections, what may represent induced gross twinning of microcline was observed to occur. In a few of these rocks there is general layering defined by nearly 100 per cent segregation of plagioclase versus microcline versus quartz.

The folded types examined appear to have undergone a general recrystallization of feldspar and quartz subsequent to the folding; neither exhibits marked preferred orientation or even strain effects. The biotite of these shows the same types of preferred orientation that it does in the non-folded types, *i.e.*, its cleavage is everywhere essentially parallel to compositional contacts. Nonetheless, it does not exhibit any notable bending or even strain effects. The amphibole of the folded types is of similar occurrence and character as the biotite.

A few layers exhibit typical crystalloblastic textures, *i.e.*, each of the chief minerals (quartz and the feldspars) contains inclusions of the others. This is especially notable in that one such rock was taken in the field as representative of a layer the rock material of which once underwent some type of flowage.

On the basis of these petrographic features it appears that the banding of the banded gneisses of the Randesund Area could represent supracrustal layering which, subsequent to deposition, has been: lithified, recrystallized, dynamically deformed and metamorphosed at least once, sporadically metasomatized, and has undergone local chemical metamorphic differentiation (probably controlled at least in part by physical adjustments) and suffered local differential cataclasis and alteration — probably *not* in this order so far as chronology of occurrence.

Some of the other events in the history of the Randesund Area banded gneisses, but apparently of little if any consequence so far as actual formation of the banding of the gneisses, are manifest by veins of and/or joint surface coatings by chalcopyrite, pyrite, calcite, epidote, and quartz; mylonitization and other cataclasis and brecciation along the "Great Friction Breccia" zone; sporadic, apparently isolated, minor brecciated zones; pre- last effective regional metamorphism basic dikes, now amphibolites — a few of these have been "bondinaged" since injection; late syn- or post-faulting pegmatite veins; and post-metamorphism basaltic dikes. The statement that these features lack significance so far as formation of the banding of the banded gneisses is based chiefly on the fact that typically they crosscut the banding. However, possible influence of movements along the Great Friction Breccia zone and of the "late syn- or post-faulting pegmatite vein" forming processes on development of the banded gneisses need to be considered further before they are dismissed as strictly impertinent.

There is no doubt, for instance, that deformation has not only affected the gneisses but may have actually controlled formation of some of the banding features. Perhaps at least some of the band affecting deformation was akin to that responsible for some of the movements along the Great Friction Breccia zone. Perhaps such features as the crosscutting relationships between the zone and the general strike and dip of the banding of the gneisses and the presence of banded gneiss fragments within the brecciated zone reflect only the last or a few late of many intermittent movements that extended over up to many geological periods. If this were true, perhaps deformative forces responsible for earlier movements along the zone did have an important role in formation of at least some of the banding of the gneisses.

Along this line, it is readily admitted that the criteria used (see Criteria section of DIETRICH, 1959c) appear to be slanted in favor of the possibility that the banding of banded gneisses reflects Relict supracrustal layering — and, although this seems on the face of it to be merely a consequence of the probability that most banding of banded gneisses can be so classified genetically, alternatively it may be that it reflects more the futility of attempting to establish anything as formed by metamorphic differentiation (*etc.*) under the influence of deformation until more is known about these processes and effects of diverse controls upon them. It appears, in fact, that until much more is known about such things that considerations in order to be "scientifically logical" will necessarily favor acceptance (or rejection) of the better known possibilities and, at most, permit only tentative approval of the relatively unknown processes on the basis of negative reasoning — to put it in the vernacular, "the cards are stacked against" the unknown. The present investigation, I fear, is exemplary.

That the syn- or post-faulting pegmatites had no effect on formation of the banding is probably true. However, many pegmatites of the area appear to be related closely genetically to certain band modification processes. Therefore, both real and theoretical difficulties arise when one attempts to distinguish among the diverse temporal pegmatite types. Although this is a vast and interesting problem, it does not appear that its resolution, no matter what, would modify greatly the conclusions reached so far as the role of pegmatite formation in formation of the bands of the banded gneisses; thus, it did not receive any but passing attention during this study.

PETROFABRICS

Rock fabric studies may serve to aid resolution of certain questions of significance to genetic considerations of banded gneisses — for examples, whether or not an arrangement of mineral grains within a given unit of a banded gneiss represents a mimetic depositional fabric or a tectonic fabric and whether or not a given tectonic fabric resulted from chiefly mechanical or chiefly chemical redistributions. However, even petrologists with great disdain for universal stage manipulations need not curb their investigations short of the simple fabric studies sufficient for most banded gneiss investigations — the fabric observations which I have found to be sufficiently complete and clarifying for most genetic studies of these gneisses can be made by megascopic observations and/or microscopic observations with binocular and unmodified petrographic microscopes. At most, a petrographic microscope with micrometer ocular and some type of mechanical stage is desirable.

Possible uses of fabric analysis in investigations of banded gneisses will become clear, I believe, in the following paragraphs. The presentation consists of attempts to answer four questions: 1) Exactly what information pertinent to genetic studies of banded gneisses appears to be discernable best through petrofabric analyses? 2) What particular observations need to be made? 3) Are any of these observations subject to alternative interpretations? 4) What methods appear to be most useable? These are followed by pertinent statements about banded gneisses of the Randesund Area.

Whether or not tectonism had any important role in the genesis of a given banding and what roles certain chemical and/or mechanical processes played may commonly be detected best from fabric analyses. Answers to these questions are practically necessary if distinctions are to be made between some banded gneisses of the Relict-supracrustal type and some of the Metamorphic Differentiation types and also between banded gneisses of the two Metamorphic Differentiation types, mechanical redistribution and chemical redistribution.

Of course nearly all fabric observations must be correlated with mineral-composition determinations to be of any real value. As has been stated by many workers, fabric analyses should start in the field. During field studies of banded gneisses one should always be on the lookout for features that may help answer questions such as these: a. Do the banded gneisses have any noteworthy spatial relationship to any zone of atypical tectonic character? b. Is the banding essentially parallel to or at an angle to larger scale lithological contacts? c. Is there any obvious preferred orientation of constituent minerals within bands? d. If so, what geometric relationships exist between same and the banding? Field observations need corroboration and usually need extension. Laboratory studies may permit answering of other such pertinent questions as: e. Are any relict, inequant clastic grains present? f. Has any of the minerals been recrystallized? g. What shape relationships with the foliation plane(s) and/or lineation(s) do the different types of grains have? h. Is there any obvious preferred orientation of crystal lattices of any mineral(s)? i. If so, is this also expressed by a preferred orientation of grain shapes? j. Has any of the constituents undergone induced twinning gliding or cataclasis? k. Are the preferred orientations more marked in some zones than in others — *e.g.*, near than away from contact zones between adjacent bands? *And*, again for reemphasis, mineral identity considerations must be correlated with many of the considerations connected with these questions if such considerations are to have any real value!

Many fabric elements can be interpreted as having gained their present forms and positions in more than one way. Tnis is particularly true of metamorphic rock fabric elements. In these rocks, it is often difficult even to classify many fabric features as, for examples, primary versus mechanically metamorphic or mechanically metamorphic versus chemically metamorphic. This is true not only because combinations and gradations exist but also because diverse processes may result in formation of essentially identical features.

Two exemplary, possibly equivocal features the interpretations of which commonly bear directly on genetic considerations of banded gneisses may be given: a dimensional orientation may reflect sedimentation, physical transposition of rigid fragments during mechanical deformation, or deformation-controlled chemical transposition (*e.g.*, according to RIECKE's principle); and, a fabric marked by some grains with obvious preferred orientations and other grains without such might, for examples, represent the results of partial recrystallization (*i.e.*, a combination of mimetic and recrystallization features) or reflect merely differences in susceptibilities of minerals to mechanical and/or chemical adjustments during metamorphism.

Another pertinent fact that one must ever be mindful of is that, in general, whereas the presence of a certain feature can constitute undeniable evidence that some certain event did occur, the lack of a feature generally can not be considered as evidence that some certain event did not occur. Also possible, of course, is that late stage dynamic deformation can result in cataclasis and/or recrystallization that will essentially mask all preexisting fabric elements, *i.e.*, the last and possibly a relatively unimportant(?) chapter in the history of a rock may be all that can be deciphered fabricwise. Despite such difficulties as these, however, fabric analyses correlated well with petrographic studies may prove extremely valuable so far as genetic considerations of some banded gneisses.

In hindsight (*i.e.*, after trying many methods), it appears to me that the fabric observations needed in order to permit answering of the necessary pertinent questions concerning banded gneisses can be made rather simply. Field observations necessary are those usually made. Field sampling needs to be modified only by taking oriented specimens. Thin sections should be made, as they usually are, essentially perpendicular to foliation. During and/or after regular petrographic examination of a thin section one should observe features that will most likely permit answering of questions such as those posed in the third paragraph of this section.

As is apparent, I believe, observations of grain surfaces, of grain shape orientations, of mineral lattice orientations, and interrelationships between shapes and lattices are particularly important. In some cases, particularly where relict clastic grains occur with no obviously preferred orientation, a second (and possibly even a third) section also perpendicular to the foliation but at some angle to the first section should be made and studied. For some rocks another section essentially parallel to foliation also may aid fabric studies. For some of the rocks constituted by grains whose greatest and least dimensions are similar I have found a method utilizing a micrometer ocular and mechanical stage to be extremely helpful in determining whether or not any preferred shape orientation exists. This method consists of determining by means of the micrometer scale the longest (or even better, the longest and shortest) observable dimensions of all grains and recording their angular relationships to some certain direction, *e.g.*, to the direction defined by the intersection of foliation and the thinsection. This method should, if possible, be used on at least three sections perpendicular to the foliation and at some angles to each other.

As the results of such petrofabric studies of the Randesund Area banded gneisses, the questions posed in a preceding paragraph of this section appear to be answered best as follows:

> Most, if not all, of the gross banding of the gneisses is mimetic depositional layering.
>
> Locally the relict layering has been modified by tectonism and chemical redistribution or possibly a combination of these.
>
> Much of the small scale "sub-banding" represents chemical redistribution to the extent that at least isochemical metamorphism has taken place.

No feature explainable only or even best as the result of strictly physical redistribution has been observed.

Even the features that appear to be explained best by chemical redistribution (*e.g.*, the selvages along some bands) are, it seems to me, just as likely to represent chemical redistribution controlled by preexisting physical and chemical band-to-band differences as chemical redistribution influenced by physical processes, *i.e.*, it appears that if any physical control existed that it may have been a static one (dependent upon composition, aggregation, effective permeability, *etc.*) rather than a dynamic one (dependent upon adjustments).

Although some of the banded gneisses occur within or near the "Great Friction Breccia" zone, most have no such occurrence. Except for the extremely local presence within and near this zone of features that may reflect greater than typical feldspathization, the gneisses are essentially similar to those quite away from the zone. This appears to suggest that tectonism has had no significant bearing on formation of the banding. Possibly corroborative is the fact that essentially identical banded gneisses have all dips from and including horizontal to and including vertical (although dips greater than 30° are most common).

Nearly all banding is parallel to major lithological contacts and most minor banding and foliation elements are parallel to adjacent band borders (even in crenulated bands). Exceptional are the chlorite-rich bands that exhibit what appears to be "shear cleavage" type foliation — — these appear to have been loci of interband slippage.

Some of the grains of zircon and magnetite that appear to be relict clastic grains are inequant. All measured have their shortest dimension nearly perpendicular to the banding. Most are "floating" grains.

Nearly all *but* these grains appear to have been formed (recrystallized?!) *in situ*. Except locally this (re)crystallization appears to have taken place rather late in the history of the rock — most mineral grains show no evidence of deformation or strain. It may be that the (re)crystallization has masked much previous history of the rock. Most of the biotite and hornblende-actinolite grains have preferred shape and optical (and thus lattice) orientations, as was noted in the preceding section. Most of the other minerals have neither type. Locally, however, as was also noted, quartz leaves are subparallel to the banding (especially in the cataclastic bands) and feldspar porphyroblasts have both shape and planar (though not linear!) lattice preferred orientations.

Thus, it can be said that preferred shape orientations correspond to preferred lattice orientations for all except the nearly equant clastic mineral grains. So far as features thus far observed, it appears that the preferred shape orientations of the clastic grains may reflect either transport of rigid grains in a less rigid media as the result of "solid rock" mechanical adjustments or original depositional orientation. The preferred shape plus lattice orientations are likewise ambiguous in that they might represent crystallization controlled by preexisting chemical differences, controlled by preexisting physical differences, controlled by deformation forces, or controlled by any combination of these. That many of these minerals occur more or less restricted to certain sub-bands may favor the chemical control. That there is typically a shape plus lattice preferential arrangement may favor one or both of the other controls.

Two things may be reiterated as possibly clarifying: That the feldspars and quartz grains do not have preferred orientation whereas the biotite and hornblende grains do does not appear to reflect only either differential (re)crystallization or even differences in susceptibility to preferred growth because commonly, even where the preferred orientation is especially marked, none of the minerals exhibits any strain effects. And, the minerals that constitute the selvages present along some bands have preferred orientations subparallel to the band borders — although this may represent mechanically controlled growth, it appears more likely that it reflects control by preexisting chemical and/or physical band-to-band differences (see description in preceding section). Also possibly suggestive is the fact that many of the amphibole grains are poikiloblastic.

That cataclasis has taken place locally is attested to by the "granitic gneisses" of some of the bands that are constituted by alternating bands of cataclastic microcline, leaf quartz, and cataclastic plagioclase. Whether or not the compositional layering reflects mechanical segregation formed as the result of adjustments in the rock or merely original sedimentary compositional layering is a moot question. In any case, apparently some bands were once subject to cataclasis and others to concomitant recrystallization or else the one type of layers (the quartz) underwent subsequent recrystallization whereas the others did not. So far as deformation features, the possibly induced gross twinning in a few of the microcline grains is also worthy of repetition here.

CHEMICAL ANALYSES

The new chemical analyses presented (Table 2) are of two groups of three adjacent bands of the Randesund Area banded gneisses. The specimens came from bands 10, 11 and 12 and 52, 53, and 54 of the section given as Table 1. The units analyzed represent five rather common lithologies and one rather rare type (no. 11). Analyses were made to supplement petrographic data with the particular objectives of determining such things as: from what original rocks these rocks may or may not have been derived and whether or not any (and, if any, what) elements appear possibly to have been introduced subsequent to original formation.

On the basis of field and petrographic data three alternatives, or combinations of them, appear to be the most likely possibilities so far as the origin(s) of these gneiss units: 1) essentially isochemical metamorphism of pyroclastic rocks, 2) essentially isochemical metamorphism of sedimentary rocks, and 3) metamorphism of either "1" or "2" with addition (subtraction, *etc.*) of such elements as potassium.

None of the analyses is similar, especially in detail, to that of any common igneous rock. The figures for the O and OH associated with the cation percentages reduced to 100.0 per cent are particularly noteworthy with reference to this. Each of the most nearly granite-composition rocks mineralwise (10, 52, and 54) has an O value which is significantly higher than the approximately 160 which is typical. In fact, only the 166.3 figure for the O of number 54 is even close to what would generally be considered as even possibly representative of a granite composition. But also noteworthy so far as an igneous genesis for number 54 is the high K_2O content — it is too high to permit correlation with any common igneous rock! Similarly, values for the amphibole-rich foliates (12 and 53) are not of magnitude that would be considered likely for mela-diorites or more basic igneous rocks — the igneous rocks that considerations are necessarily restricted to

Table 2.

Chemical analyses of two groups of three adjacent bands of the Randesund Area banded gneisses — designations are the same ones given on Table I. Analysts: Roar Solli with Alk. by Kjersti Haugen, both of Norges Geologiske Undersøkelse).

	10	11	12	52	53	54
	Weight Percentages					
SiO_2	76.71	65.72	50.35	75.66	53.25	69.58
TiO_2	.24	.29	.95	.14	1.22	.37
Al_2O_3	12.10	12.98	13.76	13.05	14.71	15.85
Fe_2O_3	.79	5.98	2.82	.70	3.47	.26
FeO	1.19	1.33	8.12	1.03	8.95	.52
MnO	.02	.05	.18	.02	.27	.02
MgO	.03	.32	8.69	.02	5.23	.02
CaO	1.19	11.95	9.48	1.10	6.46	.20
Na_2O	2.25	.21	1.87	3.18	2.04	1.83
K_2O	4.97	.14	1.54	4.36	2.61	10.70
P_2O_5	.03	.13	.27	.08	.22	.06
H_2O^-	.06	.04	.15	.09	.10	.04
H_2O^+	*.26*	*.79*	*1.64*	*.45*	*1.33*	*.32*
Total	99.84	99.93	99.82	99.88	99.86	99.77
SG	2.63	2.97	2.98	2.62	2.93	2.64
	Approximate Cation Percentages					
Si	73.2	65.2	47.8	72.0	50.8	65.1
Ti	.2	.2	.7	.1	.9	.3
Al	13.6	15.2	15.4	14.6	16.8	17.5
Fe^{+++}	.6	4.4	2.0	.1	2.5	.2
Fe^{++}	.9	1.1	6.5	.8	7.2	.4
Mn	—	.1	.2	—	.2	—
Mg	.1	.5	12.4	.1	7.6	.1
Ca	1.2	12.6	9.6	1.1	6.7	.2
Na	4.1	.4	3.4	5.8	3.8	3.3
K	6.1	.2	1.8	5.3	3.3	12.8
P	—	.1	.2	.1	.2	.1
Total	100.0	100.0	100.0	100.0	100.0	100.0
Assoc. O	175.4	175.1	154.9	174.9	158.1	166.3
Assoc. OH	1.7	5.2	10.0	2.9	8.6	2.0
Total	177.1	180.3	164.9	177.8	166.7	168.3

10. Light and pinkish gray feldspar-bearing quartzite composed chiefly of quartz, microcline, and sericitized plagioclase with minor amounts of chlorite, muscovite, biotite, actinolite, epidote, sphene, zircon, and opaque mineral(s).

11. Yellowish green epidote-rich quartzite composed chiefly of quartz and epidote with minor chlorite and sericitized plagioclase and traces of calcite, actinolite, and sphene.
12. Grayish black amphibole gneiss composed chiefly of hornblende-actinolite, plagioclase, and quartz with minor sphene and microcline and traces of epidote, muscovite, and zircon.
52. Light gray alaskitic gneiss composed chiefly of quartz, microcline, and sericitized plagioclase with muscovite, epidote, opaque mineral(s), chlorite, and biotite.
53. Dark gray biotite-bearing amphibole gneiss composed chiefly of hornblende-actinolite, biotite, quartz, plagioclase, and small amounts of opaque mineral(s), epidote, sphene, muscovite, and zircon.
54. Orange-pink feldspar-rich granitic gneiss composed chiefly of microcline with notable quartz plus traces of muscovite, chlorite, sphene, epidote, opaque mineral(s), and calcite.

on the basis of Ca, Mg, and Fe contents. Rather they are more nearly in the granitic rock composition range so far as the igneous rock possibilities are concerned. Also of importance so far as considerations of these two rocks are concerned are their low Na_2O contents and their K_2O: Na_2O ratios — both are quite unlike those of relatively basic igneous rocks! The other rock specimen, number 11, resembles no igneous rock chemically. Because of these considerations, and others, it appears unlikely that any of these rocks represents an isochemically metamorphosed igneous rock, *i.e.*, any pyroclastic rock (this aspect necessitated by the occurrences). This does *not*, however, delimit pyroclastic material with admixed sediment!

Contrariwise, all of the analyses can be correlated rather well with analyses of diverse sedimentary rocks. The following correlations are suggested as examples: 10 — feldspathic sandstone or siltstone, 11 — calcareous shale or marlstone (with original CO_2 driven off), 12 — dolomitic black shale or dolomitic ferruginous siltstone, 52, — arkose or arkosic siltstone, 53 — ferruginous graywacke, and 54 — shale (see, for example the analysis of the Glenwood shale of Minnesota, U.S.A. — GRUNER and THIEL, 1937, p. 844). Although none of the analyses shows high enough Al_2O_3 or SiO_2 contents to establish it as a sedimentary derivative, none is too low to preclude this. The Al_2O_3: alkalies + lime ratios of all these rocks are greater than one; it is lowest in unit 11 which is a high lime rock. The K_2O:Na_2O ratios are all greater than one except in units 11 and 12. Possibly anomalous are the MgO:CaO ratios which are less than one in each of the analyzed rocks — this, however, is not delimiting.

So far as the third possibility is concerned, *i.e.*, formation dependent upon additive (and subtractive) metamorphism, no chemical data appears to suggest or support such. In fact, the only possibility along this line for which support can even be construed from the chemical data appears to be silicification (excepting, of course, introduction of oxygen and silicification which is known to be a rather common process would essentially accomplish this end also). Actually, although such may have taken place, the mineralogical and other chemical data appear to support better the alternative that the rocks have not undergone a general silicification.

Despite the lack of chemical indication, however, the possibility that potassium, or even all of the constituents of many of the K-feldspars, were added during metamorphism is suggested by the presence of such features as the aforementioned K-feldspar "dents de cheval" and the local presence of different alkali feldspars, *e.g.*, perthites and nonperthites, within even individual thin sections. Because of this, other partial analyses were also made — alkali and spectrographic analyses were made of such "dents de cheval" and of the K-feldspar of the surrounding rocks. The alkali analyses show the K-feldspars of the "dents de cheval" and those of the directly surrounding rocks to be essentially identical with respect to alkali proportions. The spectrochemical analyses for each pair were found to be both qualitatively and quantitatively essentially identical — in fact, no recognizable differences were seen between any but one of the pairs analyzed and this difference was possibly dependent upon slight contamination of one of the samples. However, members of different pairs were not found to be so related! These data would appear to support either wholesale introduction of K_2O (or, again, even all the K-feldspar constituents) with local differences dependent upon original differences of part of the material incorporated in the K-feldspars *or* essentially local derivation of the material for the "dents de cheval". Other features such as the diversity of amounts of potassium from layer to layer appear to support better the relative local movement of already present potassium (*et al.*) to form the "dents de cheval" and related features. Otherwise the only apparently feasible answer would be one involving markedly differential potassium enrichment —

compare, for example, analyses 11 and 54 which are of rocks with similar Al and Si contents, similar grain sizes and types of aggregation, and which are less than 2.25 m apart in occurrence. Nonetheless, the local presence of different alkali feldspars within certain band units may favor at least local introduction rather than more local chemical redistribution. Perhaps both occurred. Alternatively, perhaps all gradations from essentially *in situ* chemical metamorphic differentiation to metasomatism involving relatively long distance movement of materials are represented. Perhaps isotope studies will serve in the future to elucidate this further.

TRACE ELEMENT CONCENTRATIONS IN "AMPHIBOLITES"

As mentioned in the Petrography section, amphibolites and other amphibole-rich foliates, similar to those that are characteristic of many metamorphic terranes, comprise most of the dark-colored bands of the Randesund Area banded gneisses. As has been stated numerous times, most amphibole-rich foliates, so far as their chemical compositions are concerned, might be derived from such diverse rocks as pyroxenitic-, gabbroid-, or meladioritic-composition igneous rocks (including intrusives, extrusives, and pyroclastics) and their direct clastic sedimentary derivatives; ferruginous, sandy, clayey limestones or marls; ferruginous argillaceous dolomites; or dolomitic shales that have been subjected to dynamic metamorphism with or without accompanying additive effects. Therefore, the presence of these rocks in the banded gneisses pose particular difficulties so far as genetic considerations.

Actually, so far as many of the amphibole-rich bands of the Randesund Area gneisses, an intrusive or even a lava flow origin can be considered precluded on the basis of field relationships — especially those pertaining to thicknesses as compared to lateral extents. Nevertheless, even here there are some amphibole-rich bands that are quite enigmatic from the genetic standpoint. This, plus the facts that nearly all reported banded gneisses are comprised in large proportions by amphibole-rich rocks and that amphibole-rich foliates of known sedimentary and known igneous parentages exist along with the ones of unknown origin within the sequence of banded gneisses of the Randesund Area prompted inclusion of a rather intensive investigation of these rocks during this study.

Of major importance to the study of any banded gneiss that includes amphibole-rich constituents is the determination of whether those constituents represent former supracrustal sedimentary rocks, supracrustal igneous rocks, or intrusive igneous rocks. For those amphibole-rich metamorphic rocks the field relationships of which are ambiguous, trace element work appears to offer promise. This is true despite the fact that two apparently valid criticisms can be leveled at the method: 1) all data are empirical and some are suspect because of being based on "knowns" the origins of which were not proved and, 2) to the present, there has appeared no way whereby this method can be used to lead definitely to distinction among metamorphosed igneous rocks versus metamorphosed pyroclastic rocks versus metamorphosed igneous-derived sedimentary rocks such as metagraywackes.

The former criticism can be quelled in part by using knowns with unequivocally proved origins. Although the latter criticism does point up some restrictions, it does not invalidate nor even greatly lessen the values of trace element studies so far as genetic considerations of the amphibole-rich components of banded gneisses: first of all, whether or not the data fit best the interpretation that the investigated rock is nonigneous (including nonigneous-derived), *i.e.*, that it is of sedimentary origin, could be of utmost significance — particularly if the answer is positive — to overall genetic considerations; secondly, even where field relationships and/or other features clearly are in harmony only with some supracrustal origin, that trace element analyses could serve to aid distinction between originally pyroclastic or igneous-derived clastic sediments and originally "normal" sedimentary rocks also might greatly enhance overall genetic considerations.

Semiquantitative spectrographic analyses of many amphibole-rich metamorphic rocks of "known" origins were made in the late 1940's by various workers (*e.g.*, ENGEL and ENGEL, 1951). They were interpreted to suggest that the diverse genetic types could be placed into two major categories, meta-igneous rocks and metasedimentites, on the basis of relatively greater concentrations of such elements as Co, Ni, Cr, Sc, V, and Cu and relatively less concentrations of such elements as Pb, Au, and Ba in the meta-igneous rocks than in the metasedimentites. In similar but much more extensive trace element studies of pelitic rocks, SHAW (1954; 1956) made quantitative measurements which he expressed in parts per million, plotted a few pairs of elements to try to ascertain the presence or lack of distribution correlation between elements, and discussed briefly possible distribution of the elements within the diverse minerals of the rocks. DIETRICH (1959d) utilized trace element analyses in a different way in his investigation of some amphibole-rich rocks of the Blue Ridge Province of Virginia, U.S.A. Briefly, this method consisted of comparing quantities of the above mentioned elements in amphibole-rich rocks of unknown origins with those in amphibole-rich rocks of known origins which occurred within the same metamorphic terrane and facies. Probably the most noteworthy advances along this line of approach are those made by HEIER (manuscript in preparation for publication by Norges Geologiske Undersøkelse) — he has plotted his quantitative data as element:element and/or element:mineral(s) ratios with each ratio selected on the basis of probable affinity considerations.

The method used during this investigation consisted essentially of the method I used earlier (*ibid.*) but modified so as to take into account some of the chief implications of the elemental affinities and element-to-mineral distribution indications found to obtain by SHAW (*op.cit.*) and HEIER (*op.cit.*). Total rocks, certain mineral combinations, and certain individual minerals were analyzed spectrographically for Co, Ni, Cr, V, Sc, Cu, Pb, Au, Ba, and Sr. Each unknown sample was run sequentially with known samples so that its pattern lay on the plate between the pattern of a known originally igneous material sample and the pattern of a known originally sedimentary material sample, each with the same general mineralogical compositions as of the unknown. The intensities of lines for each element were compared between the unknown and the known igneous and between the unknown and the known sedimentary and were classified as essentially equal to, greater than, or less than each (see Table 3).

This method is better than the method I formerly used because of its inclusion of analyses of certain mineral combinations and of individual minerals. Within a given area, it may be possible by using this "new" method to distinguish, at least in some cases, between wholly igneous materials (intrusives, flows, and "pure" pyroclastics) and contaminated or sedimentationwise fractionated materials (graywackes and tuffs with admixed sediments), *i.e.*, the "purely" igneous would tend to have all analyses closely analogous to those of known

Table 3.

Suggested laboratory tabulation sheet for trace element analyses made according to the outlined method. Results obtained from analysis of one of the Randesund Area amphibole-rich gneisses concluded to represent a metamorphosed sedimentary rock with clastic magnetite of probable igneous origin are plotted as an example.

Sample	Vanadium		Chromium		Nickel		Cobalt		Copper		Titanium		Scandium		Barium		Strontium		Lead		Conclusions[1]
	M*	I*	M	I	M	I	M	I	M	I	M	I	M	I	M	I	M	I	M	I	
Whole Rock	>	≅	>	<	≅	<	≅	<	≅	<	>	≅	>	<	<	>	<	>	<	>	Int
Magnetite	>	≅	>	≅	>	≅	>	≅	>	<	>	≅	>	>	<	<	<	≅	<	<	Ig
Amphibole	≅	<	≅	<	<	<	<	<	O	O	≅	<	≅	<	O	O	O	O	≅	>	Met

* M — metamorphic; *I — igneous. (Knowns).

[1] Ig — probable igneous; Met — probable metamorphic; Int — intermediate.

> — notably greater than; < — notably less than; ≅ — approximately equal to; O — essentially none present in either sample.

igneous material whereas the igneous-plus might have whole rock analyses and/or certain mineral(s) analyses in disagreement with the analyses of the known igneous materials. In fact, it may be that further work of this type will be useful even for such things as provenance studies and distinction between metamorphosed phenocrysts and porphyroblasts (*et al.*). Other advantages of this method are: the method is simple; one does not have to be concerned with parts-per-million analyses and ratio calculations; there is no need to include in reports of results long sections concerning equipment and methods. Although care in selection of knowns from the same metamorphic facies and terrane appears, from the theoretical standpoint, to be advantageous — at least so far as value of results — it may commonly be disadvantageous because difficulties will undoubtedly arise so far as finding such knowns in some areas.

Perhaps one "known" from the same facies and area would suffice. Perhaps even a known from the same facies but another area could be used — this would appear possible so long as the same mineral parageneses obtained and so long as no volatile elements were considered (*e.g.*, Pb and Cu should probably be delimited). This suggests that perhaps further work will show that fewer elements need consideration and perhaps even "standard quantities" can be set up as indicative of originally-igneous versus originally-nonigneous for given metamorphic facies. It also possibly suggests that such analyses may be of value so far as investigations of metamorphic facies relationships, polymetamorphism, *etc.* These aspects need further checking!! The chief disadvantage, or perhaps better shortcoming, of the method is that the work is not carried far enough to give results that are useable in quantitative geochemical distribution considerations — answering of the problem at hand is the desired endproduct.

The analyses[1] made of the amphibole-rich foliates of the Randesund Area rocks were actually more extensive than suggested by Table 3. Among other things, the light mineral fractions (plagioclase and quartz ± K-feldspar) and the "other minerals" fractions were also run — these are not included on the table because neither fraction was found to show any consistent elemental relationships that appear to bear directly on genesis. That spectrographic analyses must be correlated with petrographic data was indicated most graphically when a number of "knowns" were being checked: one "known igneous" rock was essentially lacking in magnetite and the V, Ni, and Cr contents indicated for the whole rock were lower than those for any of the other "known igneous" whole rock materials whereas analyses of its amphibole fraction and of its magnetite (enough for analysis was obtained from two large hand specimens) were essentially identical to those of the same fractions of the other "known igneous" rocks; further checking showed that V, Ni, and Cr (especially Cr) are particularly concentrated in the magnetite fractions. Similarly, most of the Sc is in the amphibole fraction; and, somewhat surprisingly, it was found that there is a higher concentration of Ti in the amphibole than in the magnetite.

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[1] All spectrochemical analyses were made in the laboratories of the Geological Institute of the University of Oslo under the direction of Jens Hysingjord, to whom I express my grateful thanks.

Of the amphibole-rich foliates from the Randesund Area that were checked all of the bands within the banded gneiss appear to represent metasedimentites *and* a few of these carry magnetite that is similar to the "known igneous" magnetites — along this line, it is interesting that in each rock where this is true the magnetite grains look like clastic grains whereas in the rocks where this is not true the magnetite typically occurs as relatively large, irregularly-shaped blebs.

GEOTHERMOMETRIC STUDIES

Geothermometers may aid greatly the clarification of certain genetic ambiguities — especially for bands of "granitic composition" (*i.e.*, any composition that could fit a quartz-bearing igneous rock) whose field relationships and petrographic features are equivocal. For example, on the basis of field and petrographic considerations it is generally easier to distinguish rocks of the lit par lit injection category from rocks of the differential anatexis category than to distingusih rocks of either the differential anatexis or the composite permeation categories from rocks of the relict supracrustal category. Even where there is evidence of flowage, it is generally extremely difficult to distinguish by petrographic, including petrofabric, methods manifestations of plastic flow from those of magmatic flow (see DIETRICH, 1960). For many such ambiguities geothermometers may offer not only an approach but perhaps the best approach to resolution.

The two-feldspar geothermometer[1] suggested by BARTH (1934) appears to be the most likely useful because it is based on common rock-forming minerals. It also has the advantage of being generally useable from the standpoint that equipment necessary for analyses is available to most petrologists. The chief disadvantages, or perhaps better contingencies, are tied up with validity considerations. BARTH (see especially 1951, pp. 148—151 and 1956, pp. 12—14) has stated, for examples, that:

1) temperature values have been fixed on the basis of unproved empirical data;

2) to at least a certain extent the total amount of sodium in the system may affect its distribution in the diverse phases;

and,

3) pressure, as well as temperature, controls the distribution.

Further, and similar statements can be said about most geothermometers,

4) at best, only the most recent lowest temperature at which equilibrium existed between the feldspar phases is recorded.

Also,

5) some two-feldspar rocks may not be susceptible to two-feldspar geothermometer analyses and most decisions as to which are and which are not are subjective.

The fact that, unlike some geothermometers, this one has not been found, to the present, to be susceptible to laboratory checking accounts for its being based on empirical data (for the best summary of such data see BARTH, 1958, pp. 10, 14—15). It is noteworthy, however, that the temperatures indicated by rocks thus far checked do fall into the order (consolidation temperaturewise) into which they would be put by nearly all petrologists on the basis of other conside-

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[1] The geothermometer thus designated in this report is based on the rule of constant ratio of distribution of a substance between two solvents and, so far as its application to this geothermometer may be stated: at constant temperature and pressure albite will be distributed between the potassium-feldspar and the plagioclase-feldspar phases with a certain ratio. Expressed by formula, this becomes:

$$\frac{\text{Mole fraction of Ab in K-feldspar}}{\text{Mole fraction of Ab in Plagioclase}} = K_{P,T}$$

rations. It is also noteworthy that Ca:Sr ratios of K-feldspars versus Ca:Sr ratios of plagioclases of some rocks have been found to suggest similar distribution trends (HEIER, personal communication). Also possibly corroborative is the fact that thermodynamic considerations concerning one of the border cases of the three-feldspar system, the Or-Ab border system, are essentially in harmony with the experimentally determined solvus for the same system (BARTH, 1951; BOWEN and TUTTLE, 1950).

That the total amount of sodium in the system may affect its distribution in the two feldspar phases has been suggested on the basis of theoretical considerations by BARTH (1956, pp. 12—14) and as an implication of some experimental work by WINKLER and VON PLATEN (1958, pp. 99—102; see also discussion of this in HEIER, 1959). Actually, both the theoretical considerations and experimental data appear mainly to suggest that the two-feldspar geothermometer should be essentially relegated to determination of relative temperatures within relatively small zones and that rocks with relatively low (<2.0 per cent) or high (>6.5 per cent) Na_2O contents should be delimited from such considerations. BARTH (*op. cit.*, p. 14) has suggested similarly that the geothermometer should be approximately valid for rocks in which "plagioclase is in the range 10—30 An and the alkali feldspar in the range 10—30 Ab."

Along this line, there are other aspects that need investigation — for examples: a) possible effects of the presence of one versus other phases of K-feldspar, including perthitic variants — especially their possible control over process(es) and completeness of sodium distribution between and within diverse phases during metamorphism (BARTH, 1956, p. 11, has noted, for example that "It can be safely assumed that albite will find it more difficult to enter into the ordered lattice of microcline than into the disordered one of orthoclase."); b) possible effects of the presence of one versus other composition plagioclase feldspars, including zoned versus unzoned ones; c) possible effects of grain sizes of the rocks; and, d) possible effects of types of aggregation of the rocks. This last aspect (d) may initiate another question so far as at least the use of the geothermometer for some low grade metamorphic rocks — *i.e.*, could there have been any albite molecules, or perhaps better the elemental constituents of albite molecules, removed between the times of formation of the two feldspar phases(?). (If some of these possible controls actually do exert themselves, even the use of the geothermometer to establish whether or not there was interlayer thermal-equilibrium would be subject to question.) Perhaps, although on the basis of certain theoretical considerations this seems unlikely, other distribution-between-solvents "geothermometers" may be present and prove more useable — for examples: Ca in one versus the other feldspar phases, trace amounts of such elements as Sr and Pb in one versus the other feldspar phases, or even such elements as Ge in two or more of the diverse silicate minerals.

Most possible effects of pressure on geologic processes and their rock products are known incompletely, if at all. Perhaps in the case of two-feldspar geothermometric considerations, because of the states in which equilibria are probably established and because of the rather restricted volumes involved, pressure effects are essentially negligible. In any case, however, this is a "wide open" field for future study and, therefore, most past and present day geologic interpretations must be considered "pressure dependent".

Perhaps for those who use this geothermometer, despite such contingencies as those noted, the fact that is of utmost importance is that for many rocks the true significance of the temperature obtained from two-feldspar geothermometric studies can not be realized unless the thermal history of the rock is known. This is true because the most recent lowest temperature at which equilibrium existed between the feldspar phases is necessarily what must be recorded. This, of course, means that even if it is assumed (even if corectly so!) that the present contents of the feldspars do reflect former equilibrium conditions, the temperature that obtained at the time of last attainment of these conditions, and thus the temperatures "measured", could have been much lower than the highest temperature to which the rock material was exposed.

Probably the thermometer is best for rocks formed as the result of the relatively rapid cooling of a magma — the temperature recorded would be essentially that of consolidation (1)[1]. Probably the most completely misleading temperatures that may be obtained by using the thermometer will be those obtained from two-feldspar analyses

[1] This and subsequent numbers in this and the next four paragraphs refer to designations given pertinent diagrams in Figure 1.

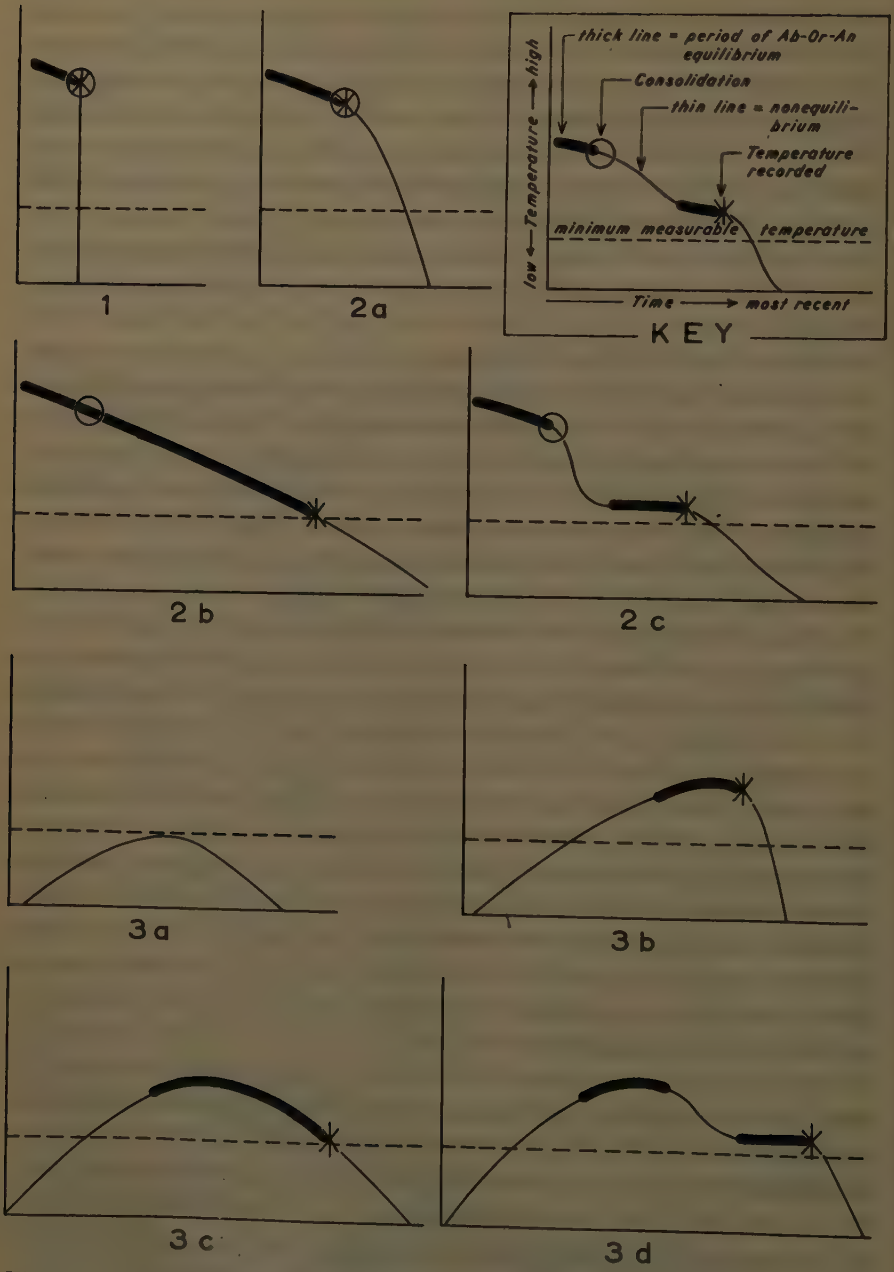

Fig. 1. Generalized possible thermal history curves for: 1. extruded or intruded-into-"cold"-rocks magma, 2.a intruded-into-"cool"-rocks magma, 2b. very slowly cooled magma, 2c. erratically slowly cooled magma, 3a. low grade metamorphism, 3b. higher grade metamorphism with slow cooling during waning stages, 3c. higher grade metamorphism with very slow cooling during waning stages, 3d. higher grade metamorphism with erratic coolings — even diaphthoresis — in post-highest temperature metamorphism period.

of exposurewise geologically isolated, non- to slightly-metamorphosed, quartz-cemented, arkosic sedimentites that consist chiefly of granule-sized, monomineralic fragments — the temperature indicated could be as high as a magmatic temperature (2a) whereas the rock as such might never have reached a temperature high enough to exceed the minimum temperature measurable by this geothermometer (3a).

Innumerable possible temperatures ranging from the consolidation temperature to the minimum temperature measurable by the geothermometer could be recorded for a rock that cooled relatively slowly after consolidation from its magma — Three possibilities will serve as exemplary: a) the equilibrium conditions existent at the time of consolidation of the feldspar phases might be "quenched in" and never subsequently upset — the consolidation temperature would be recorded (2a); b) after consolidation, equilibrium between the phases might be maintained, *i.e.*, continuously changed with changing temperature, by some such process as ionic or molecular diffusion through the "solid" rock a part of or all of the way down to the minimum temperature measurable by the geothermometer — this lowest temperature, possibly the minimum measurable, at which there was equilibrium among the phases would be recorded (2b); c) after consolidation, at some period(s) during subsequent cooling, temperature and other conditions might remain constant long enough for a recrystallization of and reestablishment of equilibrium among the feldspar phases to occur — the temperature of recrystallization would be recorded (2c). Obviously, in the two latter cases submagmatic temperatures would be recorded despite the fact that many petrologists would consider at least the former (b) and probably both (b and c) rocks to be igneous.

Perhaps some petrologists will object to this last statement on the basis that they may consider the last two rocks to be, instead of igneous, something like "of ultimate igneous origin but affected by subsequent auto-metamorphism". This, however, merely gets into taxonomical considerations concerning one of the "shadow zones" of a classification of natural things amenable only to strictly arbitrary division and is of no real importance to this discussion. Nonetheless, these considerations are extremely important so far as such things as the origin of "granite" controversy because it must be realized fully that so far as application of this geothermometer to genetic considerations of problematic igneous versus metamorphosed sedimentary rocks that *whereas a magmatic temperature can be cited as evidence for a magmatic origin that a submagmatic temperature cannot be cited as evidence against an ultimate magmatic origin!!*

For metamorphic rocks that become heated sufficiently long above the minimum measurable temperature for equilibrium to be established among the feldspar phases, the temperature measured would depend chiefly upon the conditons during and the speed of cooling down in the waning stages of metamorphism. Of importance here, of course, are the age-old and still unanswered questions concerning what state(s) rock materials are in during metamorphism (review, for example, the discussion in the section, Petrofabric Analyses) and also the above mentioned questions as to whether or not chemical equilibrium between the three feldspar phases can be established by solid diffusion and/or other types of migrations independent of or in conjunction with recrystallization. Empirical evidence appears to favor the establishment of such equilibrium conditions during metamorphism, which is generally considered to involve changes within "solid rock". However, to the present few features have been recognized in any metamorphosed rocks that appear to offer unequivocal evidence concerning the mechanisms of or the state(s) of the rock materials during metamorphism.

Probably so far as the use of the two-feldspar geothermometer the best guesses on the basis of present evidences are: a) slow cooling would be likely to be manifest temperaturewise by the minimum temperature measurable by the geothermometer (3c); b) rapid cooling would result in the "quenching in" of approximately the maximum temperature attained (3b); and c) typically, probably something between would be measured (*e.g.*, 3d, although this diagram actually suggests diaphthoresis). In any case, here again as with slowly cooled magmatic rocks, a high temperature for any mineral assemblage would be of value to genetic considerations whereas a low temperature would be of little or no use except so far as its probably indicating that a slow cooling occurred after the attainment of the peak temperature of metamorphism.

All of these outlined possibilities have necessarily been of rocks with "simple" thermal histories. As is quite apparent, I believe, a rock with a "complex" thermal history might contain feldspars whose

Ab-Or-An equilibrium relationships could reflect just about any part of the rock's history. This further emphasizes the fact that only high temperatures, so far as a given paragenesis is concerned, are really very significant.

Some of the reasons why certain two-feldspar rocks may not be susceptible to two-feldspar geothermometric analyses are mentioned in an above paragraph concerned with sodium distribution factors. The geneses of perthites and zoned plagioclases and their implications so far as interpretations of geothermometers involving them are also of extreme import. For example, if the potassium feldspar is perthitic, to be useable the perthitic quality must have originated as the result of exsolution or simultaneous crystallization of the phases from an originally homogeneous alkali feldspar and not as the result of replacement. This is extremely difficult to establish unequivocally in nearly all cases (See, for example SCHWARTZ, 1931 and 1942 for some possible criteria). Relative impoverishment or depletion of rubidium may be a means of recognizing perthites of some certain compositions which were originally formed from a homogeneous phase (TAYLOR and HEIER, 1958); comparison of structures with those known to have formed by unmixing from originally homogeneous solids (*e.g.*, pearlitic structures in some alloys) offers another questionable possibility (DIETRICH, 1954, pp. 522—523). Despite some examples which have been interpreted otherwise (*e.g.*, DIETRICH, *op. cit.*), it might be a good "rule of thumb" to eliminate pure-albite perthites — albite is a well known replacement mineral. On the other hand, if the plagioclase of the perthites is not pure albite, what does this mean so far as the initial tieups between the potassium-feldspar, albite, and anorthite molecules? — does it suggest formation of them by simultaneous crystallization or some other means rather than as the result of exsolution from a preexisting homogeneous phase *and/or* was there a significantly greater affinity between the albite and the anorthite molecules than between, for example, the albite and potassium-feldspar molecules even within the socalled homogeneous phase? — if so, what does this mean so far as using such perthites for these analyses? — does it suggest that their use should be disallowed merely on the basis of the original tenet (BARTH, 1951, p. 148)? Certainly all perthites that appear to have been formed as the result of corrosion must be eliminated from considerations. Another extremely significant question arises as to what further considerations need to be made in light of the complete exsolution cases suggested as possible by TUTTLE (1952) and found probably to exist by DIETRICH (1954).

"Results" from rocks with zoned plagioclase must also be delimited or at most considered to be but suggestive — perhaps the best alternative where data is desired and only such plagioclases exist within the rocks is to use both the highest and lowest An-content zones as limiting values.

Rocks with two different potassium feldspars, even where it is obvious that one is probably original and the other of late introduction, are most difficult to use in all cases and essentially impossible to use in most cases, chiefly because it is nearly impossible to separate two different potassium feldspars from the same rock for the necessary analyses.

Data given for rocks with two plagioclase feldspars should be viewed with complete realization that use in calculations of An-values determined for one type of grain instead of those determined for the other type(s) depends upon subjective considerations of the investigator — even if these are clearly stated and appear to be quite logical, questions necessarily remain.

Despite shortcomings of this geothermometer, the fact that both empirical data and theoretical considerations suggest that it may, in at least some cases, measure magmatic temperatures points out that it is extremely useful. This is the main reason it was used during this investigation. Another reason, however, was that multilithic rocks such as banded gneisses, by their very natures, contain feldspars the relationships of which bear directly on some of the important questions raised in the above discussions. Thus, it was believed that inclusion of this part of the study also might have the added value of helping to answer some of these questions. Along this line, feldspars were run from 1) diverse parts of a large specimen the feldspars of which have a wide range of grain sizes, 2) rocks from nearby bands with different plagioclase feldspars, 3) rocks from nearby but differently composed bands with what appear microscopically to be different alkali feldspars, 4) different parts of the same unit that appear to be of different metamorphic grade, and 5) different "pure" alkali feldspar fractions from the same handspecimen.

Table 4. Feldspars from banded gneisses of the Randesund Area.

	Grain-size check (1)*; see Fig. 4				Feldspar features check (2 and 3)			Metamorphic grade check (4). Pure fractions check (5)			
Sample Number	1	2	gm	3	66	Alt	42gm	8	7i	7ii	7iii
Na_2O	1.15	.90	.77	.70	1.56	1.45	1.39	1.10	.40	.76	.86
K_2O	15.12	15.24	15.33	15.98	13.72	13.97	13.97	14.38	16.32	15.64	15.54
Normative Ab	9.7	7.6	6.5	5.9	13.2	12.3	11.8	9.3	3.4	6.4	7.3
Normative Or	89.4	90.1	90.7	94.5	81.1	82.6	82.6	85.0	96.6	92.5	92.0
Mol. prop. Ab	10.3	8.2	7.0	5.9	15.0	13.6	13.2	10.4	3.6	6.8	7.8
Mol. prop. Or	89.7	91.8	93.0	94.1	85.0	86.4	86.8	89.6	96.4	93.2	92.2
Ab of associated plagioclase	95	95	95	95	94	85-88	85	84	95	95	95
k	.108	.086	074	.062	.16		.155	.124	.038	.072	.082
Temperature, °C (From two-feldspar thermometer)	<400	<400	<400	<400	435	420	420	~400	<400	<400	<400
Temperature, °C [from solvus of system Or-Ab (BARTH, 1959)]**	365	330	320	280	440	420	410	370	240	305	325

* Numbers in parentheses refer to numbers given in text pp. 51-52.

** These are minimum temperatures and most nearly correct for the lowest Ca-content-in-feldspars rocks (here: 1, 2, groundmass, 3, 66, 7i, 7ii, and 7iii). The Or-rich part of the Or-Ab system solvus temperature curve and the k value for the two-feldspar geothermometer temperature curve nearly coincide when plotted on the same base in the + 400° C temperature range.

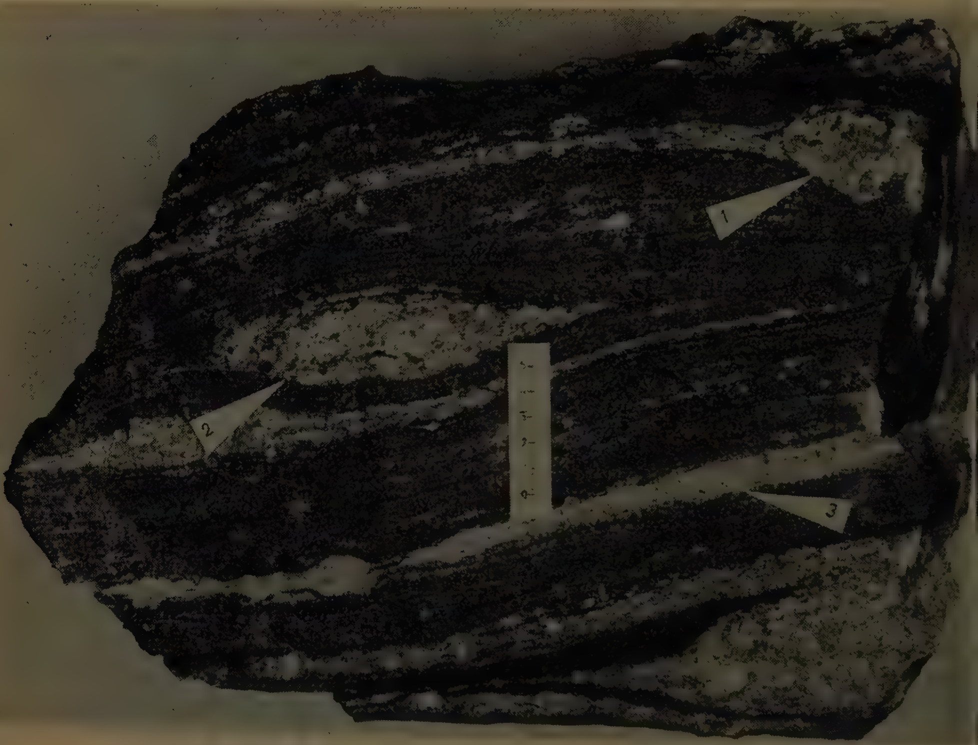

Fig. 2. Specimen from which samples were taken to check possible relationships between grain size and amount of Ab in Or. Numbers correspond to those on Table 4: 1 is essentially one large grain of microcline with a few included relatively large grains of plagioclase and quartz; 2 is similarly constituted but is intermediate in grain size between no. 1 and the gneissic host; 3 is an extremely fine grained band in the gneiss with the size of its feldspar notably less than that of the feldspars of the gneiss host ("groundmass" on the table).

The method used was that outlined by BARTH (1956, p. 18).[1] The determined data, calculated *k* values, and approximate temperatures based on the latest empirically established curves of BARTH (1956a, Fig. 1) are given on Table 4.

None of the determined temperatures exceeds 450° C. Many are in the range below that considered definable by the method. This is a consequence of the feldspars' containing lower than the suggested "plagioclase ... in the range 10—30 An and the alkali feldspar in the range 10—30 Ab" (BARTH, op. cit., p. 14). Therefore, most of the data may lack significance even so far as offering checks on the above listed aspects.

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[1] Separations were made with the aid of Mrs. Borghild Nilssen of the Mineralogisk-Geologisk Museum; flame photometer alkali analyses were made by Miss Kjersti Haugen of Norges Geologiske Undersøkelse. I acknowledge these aids to the investigation with grateful thanks.

If they do have any significance, the following tentative conclusions appear to be in order:

1) The amount of Ab in Or may be related to grain size of the alkali feldspars (here the relationship suggested is that amount of Ab in Or varies directly with grain size) — this may reflect control over incorporation of Ab in the Or grains during formation or control over subsequent retentivity. However, even *IF* further work corroborates this tentative conclusion, the thermometer still would appear to be useable so long as grain sizes of feldspars are considered. On the other hand, corroboration of this conclusion would arrest (or at least make quite suspect) overall considerations such as those involving temperatures of formation of, for example, gneisses and spatially associated pegmatites.

2 & 3) Specimens 66, Alt, and 42 gm all occur in close proximity within the banded gneiss and thus probably last had an equilibrium among Ab, An, and Or attained, if such was attained, at essentially the same temperature. No. 66 has a plagioclase of notably different Ab-content than those of nos. Alt and 42 gm; specimen Alt appears nonperthitic in thinsection whereas specimens nos. 42 gm and 66 are perthitic. Despite these apparent differences all give similar k values (and, of course temperatures). This would appear to corroborate the original tenet — that the distribution law is applicable to albite molecule distribution in the alkali versus plagioclase feldspar phases.

4) Specimens 7 and 8 are from one of the meta-arkose units indicated on the BUGGE—DIETRICH map (DIETRICH, 1959). Under the microscope the rock exemplified by specimen no. 7 appears to be of lower grade than that exemplified by specimen no. 8. This also appears to agree with the regional relationships. The geothermometric data as given by the two-feldspar geothermometer appear to corroborate this relationship, or perhaps it can be said conversely that the relationship plus the correlative temperature determinations substantiate the usefulness of the geothermometer.

5) Specimen no. 7 was chosen to check whether or not all alkali feldspar grains in a given rock have the same Ab:Or molecular ratios and also if not, whether or not the specific gravity separation method used is sufficiently sensitive to separate the diverse fractions. This rock was chosen because all of its alkali feldspar grains are essentially the same size and the rock contains a relatively large proportion of alkali feldspar. It *cannot* be said, however, that type of aggregation — including tie-up with plagioclase grains — is such that "pure" grains only were present after grinding. The last four fractions appeared upon examination to be pure alkali feldspar. The last three — 7i, 7ii, and 7iii, listed from last fraction to third-from-last fraction — were analyzed. As is evident the Na:K ratios vary just as would be expected if the individual grains or parts of grains were not all of the same Ab:Or contents and were separated on the basis of specific gravity, *i.e.*, the greater the Ab:Or ratio the lighter in weight the feldspar. This may be the answer. On the other hand, it may be that this merely reflects lower and lower (below the limit of discernability by examination methods generally utilized) contamination by the plagioclase feldspar. Perhaps the reliability (and implications) of these findings can be checked further by correlating samples so separated with those merely hand picked, those separated by a combination of these methods, and those separated by other means — preferably on a relatively coarse grained rock so the hand-picking plus liquid separation method can include an intermediate grinding step to assure breaking of individual grains and perhaps even a sorting as to part of grain (*e.g.*, core versus border) and thus also check whether or not even these are homogeneous as to Ab:Or contents throughout. In any case, the data appear to show that the gravity method of separation as used is extremely sensitive.

All of these aspects need further investigation — certainly no conclusions other than tentative ones can be made on the basis of so meager data.

So far as the Randesund Area banded gneiss units are concerned, all temperatures measured are below what are generally considered to be magmatic temperatures — in fact, all are in the temperature range generally believed to obtain in the high greenschist-low amphibolite metamorphic facies, *i.e.*, they center around the temperatures generally attributed to the epidote-amphibolite facies. This agrees well with the mineral parageneses of the rocks. The one rock (no. 66) believed on the basis of field features and texture to represent a layer the material of which possibly underwent partial anatexis attained a temperature of at least 435° C according to measurements made. It possibly attained a higher temperature. However, perhaps the fact that none of its associated rocks appear to have reached any great temperature, on the basis of their parageneses or indicated temperatures favors the lower temperature possibility. *If* this is true, the evidenced mobility of this rock material must have been of a plastic nature.

GENESES

The applicabilities of diverse possible geneses for banded gneisses to the Randesund Area gneisses are considered in this section according to the order of the suggested classification.

Relict Igneous. No data support formation of any of the Randesund Area banded gneisses as the result of magmatic flow, differentiation, or segregation. Quite the contrary, such features as the sizes, shapes, and compositions (especially the marked layer-to-layer chemical as well as mineralogical compositional differences) of the bands do not appear to be even reconcilable with such explanations.

Supracrustal Stratification. There are many features the presence of which support the possibility that the banding of the Randesund Area banded gneisses reflects supracrustal depositional layering. Some of these may be reviewed: banding is concordant with major lithological "breaks"; marble and impure quartzite units occur within the same sequence as the banded gneisses; features that appear to be explained best as reflecting scour-and-fill and cross-bedding occur locally; some bands have typically sedimentary compositions; "heavy minerals" of some bands have clastic grain shapes; some of these "heavy minerals" constitute relatively high percentages of certain layers within and essentially parallel to the bands; and, more than one variety of certain minerals occur within some individual bands. Further, sizes and shapes of some bands can be harmonized

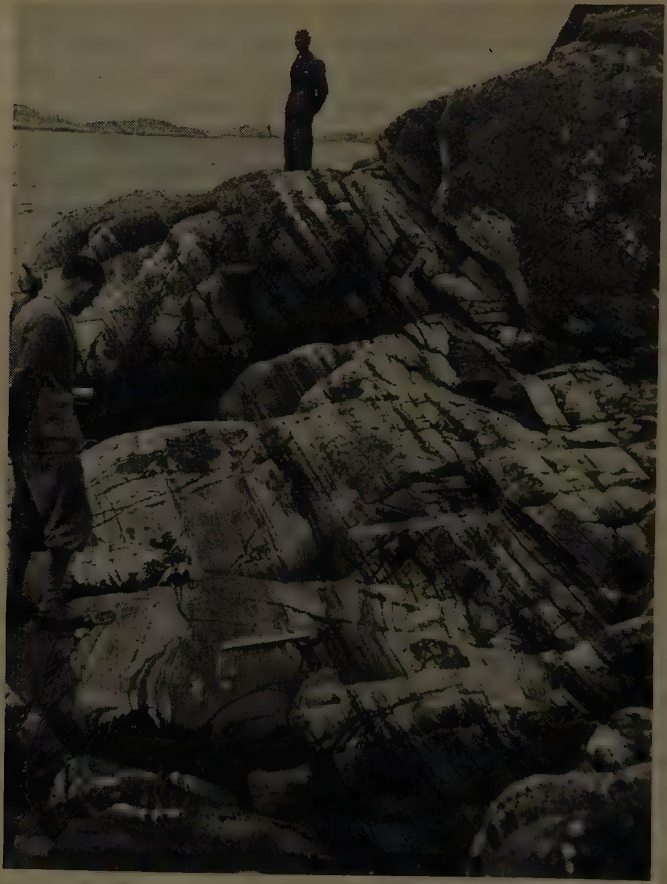

Fig. 3. Banded gneiss — southeast side of Herøen; the chiefly relict supracrustal type gneisses of this locality show evidence of having been modified by mobilization and local permeation and/or metamorphic differentiation.

logically with a supracrustal origin whereas they cannot be with any other origin. Actually, on the basis of all known data it appears at least possible that most of the Randesund Area banded gneisses may represent essentially isochemically metamorphosed supracrustal rocks. However, it is equally apparent that at least locally some characteristics of the presently observable banding also probably mainfest differential anatexis, chemical metamorphic differentiation, and meta-

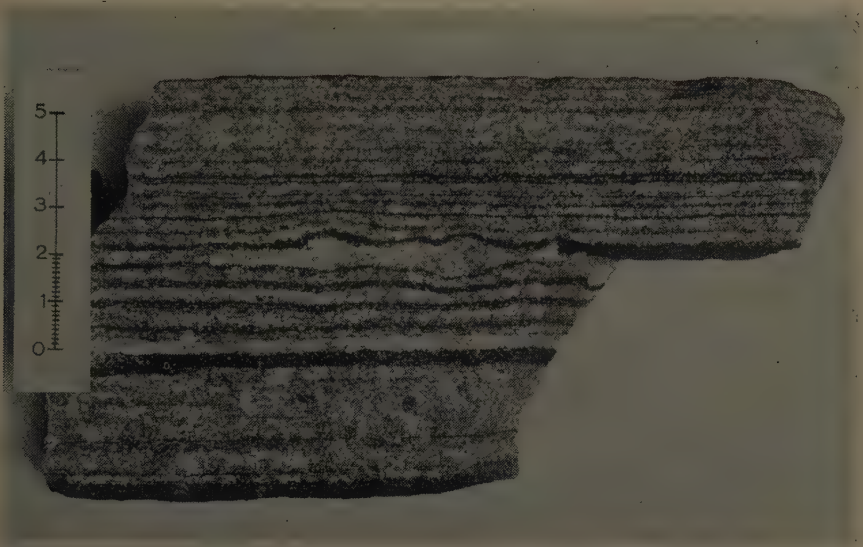

Fig. 4. Close-up of finely banded gneiss — from new highway cuts in central part of the Randesund area.

somatism. In most cases, it is extremely difficult, if not impossible, to determine by presently known methods of investigation how much these processes actually modified the chemistry of the original supracrustal rocks. Some aspects of these questions are discussed under their pertinent subheadings of this section.

So far as characteristics of the supracrustal sequence itself — on the basis of all presently known data this sequence appears to have consisted chiefly of alternating layers of shales, siltstones, and fine-grained sandstones (most of which were impure) with sporadic layers of dolomitic and/or calcareous modifications. The regularity, relative thinness, and relatively great lateral continuity of many of the layers suggest deposition in rather quiet water. No evidence bearing on the position of the source area has been recognized.

Composite Migmatization. As alluded to in this paper migmatization has as a prerequisite that one of its members solidified from a magma. (This delimits the rocks termed "migmatites" by some workers which were formed chiefly by metasomatic processes — the

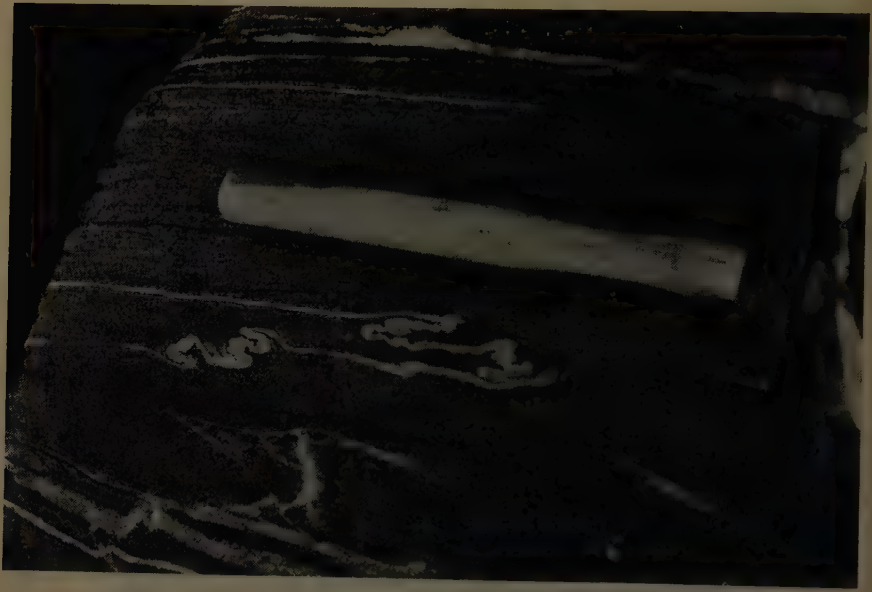

Fig. 5. Banded gneiss — from island directly south of Randøy; the chiefly Relict supracrustal type gneisses of this locality show evidence of having been modified by migmitization, probably dependent on differential anatexis and relatively local movements of the so mobilized material.

applicability of such permeation processes to the origin of the gneisses is considered under the succeeding subheading.) It also is considered that the magmatic part of a migmatite can be injected or can arise essentially *in situ* as the result of complete or partial anatexis.

Some of the bands of the Randesund area banded gneisses appear to have been relatively mobile at some time during their history. Compositions and textures of the rocks that appear most likely to have been magmatically mobile are ambiguous. As a result of geothermometric studies thus far completed one of the bands that appeared to have once had mobility was found to have once reached a temperature of at least 430° C. This certainly would not generally be considered to be within a magmatic temperature range. The local presence of ptygmas, if formed according to the development in a passive host hypotheses (DIETRICH, 1959b), suggests, however, that the conditions once were such that at least some granitic composition bands may have been magmatic, *i.e.*, at least potentially mobile because of the presence of a silicate melt phase. If regional structural interpretations given in this report are essentially correct, that rocks similar to those of the granitic Telemark Province possibly exist beneath the banded gneisses may be considered as permissively corroborative. Shapes, sizes, and compositions of the bands that possibly were magmatic at some stage in their histories essentially require that, if they ever were magmatic, the magma was not injected from without but arose essentially *in situ*, *i.e.*, where (and if) any parts of these gneisses may be considered as migmatites they are of the differential melting type and not of the injection type. Although it may very well be that the evidenced mobility merely reflects former plasticity it also may manifest anatexis.

Composite Permeation. Pyrite that occurs as joint surface coatings; quartz, epidote, and other minerals that occur in veins; and, the feldspar of the "dents de cheval" which have compositions different from those of the feldspars in the surrounding rocks probably owe their existence to some permeation process. The feldspars of rocks in which the compositions of the "dents de cheval" and the surrounding material are essentially identical also possibly represent the results of permeations. And, *if* this is the correct interpretation, perhaps some feldspar-rich bands with no "dents de cheval" also were feldspathized as the result of permeation processes. *But*, it also appears at least possible that at least both of these last two features may represent merely essentially *in situ* redistribution and recrystallization. This remains a moot question. However, the lack of any feldspars in many bands, the general concentration of "dents de cheval" along certain zones, the preferential orientation and alignment of at least some of these relatively large feldspar grains, the local association with metamict yttrium-rich allanite, and that although some of the "dents de cheval" type feldspars do have the same composition as the feldspars of the surrounding rock others do not have are all facts that seem to fit best the conclusion that there has been at least local feldspathization (or perhaps only differential potassium-enrichment). However, it also can be concluded on the basis of these

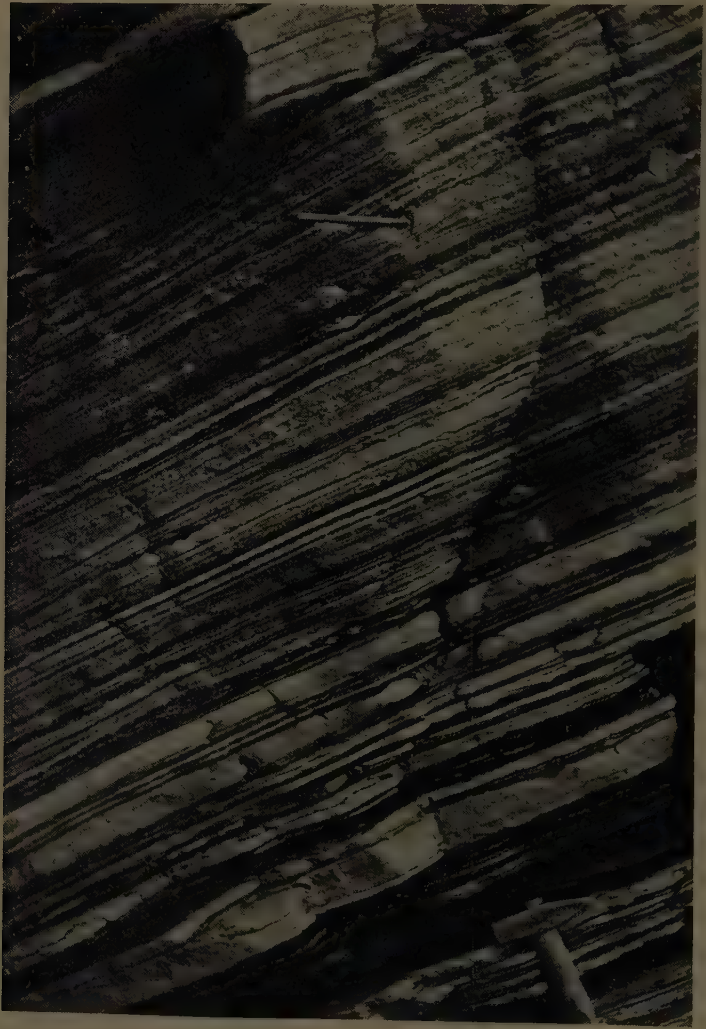

Fig. 6. Banded gneiss — from near south end of point on west side of Fidjekilen Fjord; the chiefly Relict supracrustal type banded gneisses of this locality show evidence of having been modified by permeation processes and/or metamorphic differentiation with resultant formation of numerous feldspar "dents de cheval".

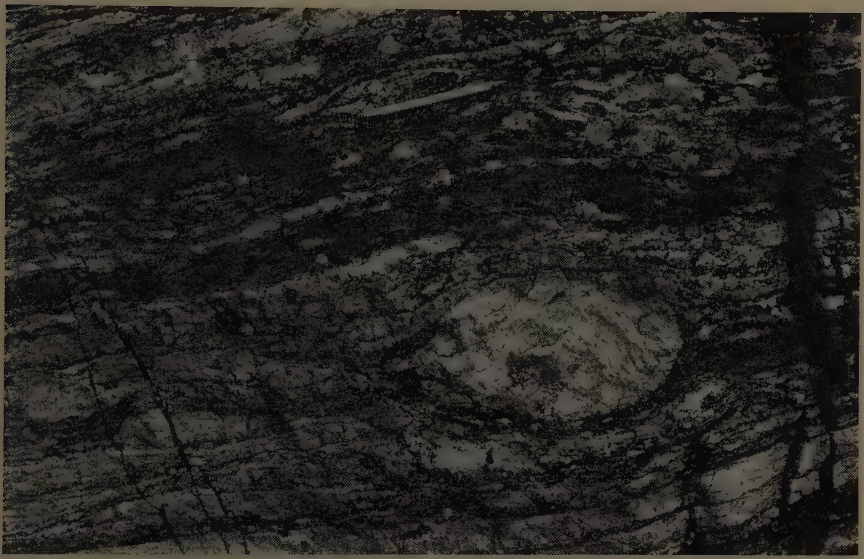

Fig. 7. Close-up of one of the "dents de cheval" as shown in Fig. 6.

data that, in the true sense of the word, there has been no overall feldspathization. Further, it is quite apparent that formation of the banding of the gneisses cannot be ascribed to permeation processes — at most, such processes locally accentuated preexisting banding.

Metamorphic Differentiation. Considerations of possible relationships between chiefly chemical and chiefly mechanical metamorphic differentiation give rise to numerous questions concerning probably one of the least known of all geological domains — possible conditions and processes of metamorphism. In fact, it appears that until we know more about effects upon such processes as ionic and molecular diffusion and recrystallization of original composition — both mineral-constituentwise and aggregationwise, of temperatures, and of both hydrostatic and differential pressures that "conclusions" made as the results of genetic considerations like those made in conjunction with this investigation about metamorphic differentiation as a possible mechanism for formation of banded gneisses must be strictly tentative.

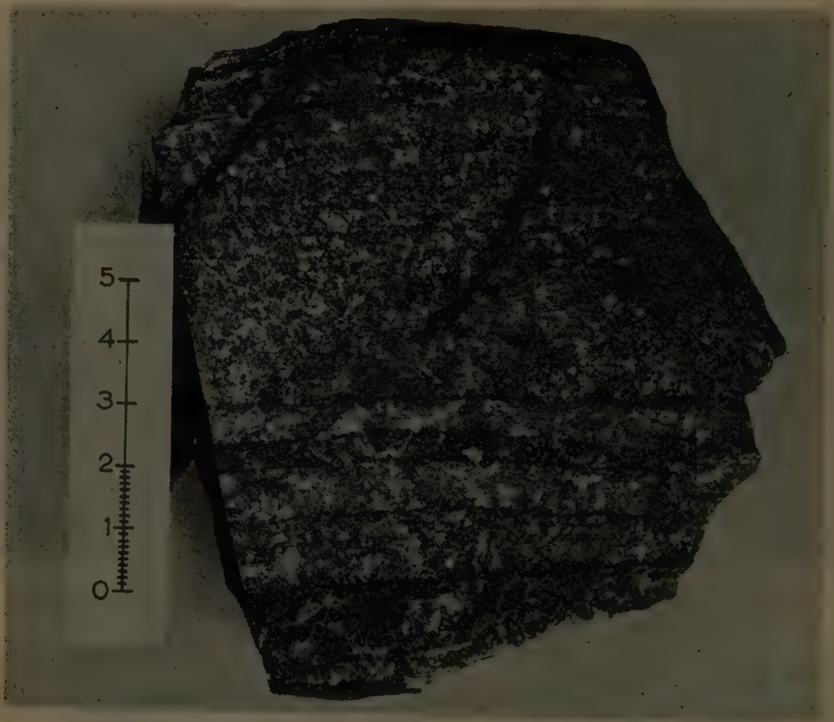

Fig. 8. Banded gneiss — from central part of west side of Fidjekilen Fjord; the chiefly Relict supracrustal type banded gneisses of this locality show evidence of having been modified by metamorphic differentiation.

Some of the banded gneisses of the Randesund Area are marked by features that may manifest metamorphic differentiation processes. Four may be reviewed: 1) locally a few chiefly quartz and microcline bands have selvages of nearly pure biotite; 2) some feldspar "dents de cheval" are of the same composition as the feldspar of the surrounding rocks; 3) locally bands with cataclastic fabrics occur between bands within which there are no evidences for cataclasis; and, 4) some layers are marked by a foliation (cleavage ?!) at an angle to the general banding.

The biotite-rich selvages may reflect original sedimentation-cycle compositional differences or they may manifest some metamorphic differentiation or metasomatic process(es). The feature appears to me to represent depletion from the central bands and concentration of the depleted materials to form the selvages (*i.e.*, they are "basic behinds"). Perhaps the selvages are "basic fronts" formed because of additions to the central bands (?) — in which case they probably would be considered to be results (indirect) of the permeations responsible for the additions to the central bands. Perhaps they represent more local redistributions dependent upon chemical gradients set up as the result of something such as dilatency or some other differential interlayer movements (?) — in which case they probably would be considered to represent metamorphic differentiation.

The "dents de cheval" also might represent either metasomatism or metamorphic differentiation. The fact is, as already mentioned, these processes are probably extremely close akin with their chief differences being distances moved by the involved materials.

The differential cataclasis might be considered by some to represent a sort of mechanical metamorphic differentiation — however, a more likely explanation appears to be that it represents deformation controlled by pre-deformation lithologies, *i.e.*, under conditions of shearing certain lithologies are deformed chiefly cataclastically whereas others are essentially unaffected or changed chiefly by recrystallization.

The cleavage at an angle to banding within some of the bands also probably reflects only especially well-defined reactions of certain lithologies to deformation movements.

So far as formation of the overall banding of the Randesund Area gneisses, many of the observable features of the gneisses appear to be out of harmony with and some essentially preclude the possibility that the banding could have been formed as the result of any metamorphic differentiation process(es). Consider, for examples, the areal distribution of the gneisses and the sizes, shapes, and compositions of the bands.

It appears that at most metamorphic differentiation may have locally modified the banding of the Randesund Area gneisses.

SUMMARY

In the field the banded gneisses of the Randesund Area can be seen to belong to the same sequence as relatively large units of meta-arkoses and small lenticular masses of impure marbles of undeniably supracrustal origin. The banding of the gneisses is concordant to major lithological contacts. Petrographically the bands are of such diverse compositions as nearly pure quartzite, gneissic arkosic quartzite, epidote-quartz gneisses, two mica schists, amphibole-rich gneiss, and amphibolite. Both the parageneses and chemical makeups of the units appear possibly to reflect originally supracrustal formation compositions. Trace element analyses of some of the amphibole-rich foliate units appear also to represent original sedimentary formations. Geothermometric studies appear to reflect last attainment of equilibrium among Ab, An, and Or feldspar molecules as having occurred at temperatures generally correlated with the high greenschist-to-low amphibolite facies conditions. These and other data appear to support best an eclectic origin for the banded gneisses of the area: control by regional supracrustal stratification over presently observable banding, essentially isochemical metamorphism, local chemical metamorphic differentiation, local differential cataclasis, local formation of features best explained as the results of spatially restricted and/or possibly long distance movement of K_2O (or even of all K-feldspar constituents), and local plastic flowage and/or magmatic flowage in accompaniment to partial anatexis.

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Manuscript received June 5, 1959.
Printed February 1960.

CONTRIBUTIONS TO THE MINERALOGY OF NORWAY

No. 4. New finds of coal blend

BY

BRIAN PLAYLE

In his paper entitled "Coal Blend and Uraniferous Hydrocarbon" (1956), DONS describes some twenty localities in the Oslo region where coal blend has been found. It may be of interest to record four new occurrences.

During a survey of the Permian sediments and lavas in the Lier-Asker region, about 20 kilometres WSW of Oslo, coal blend was found by the author at four localities; two in the rhomb porphyry and two in the basalt lava.

Locality 1. Along the path leading to Asdøltjernet from Asdøl, Lier. Here, about 100 metres up in the rhomb porphyry (RP_1, Kolsås type), coal blend occurs associated with calcite in a vesicle. The coal blend forms small globules and ovoids within the calcite, varying in size from 5.0—0.1 mm. This association may be genetically related to the host lava, or to a nearby dike of rhomb porphyry.

Locality 2. North of Semsvannet, Asker, a road leads from Tveiter to Rustaden. By the road side near Mobråten coal blend was found together with calcite and fluorite in a vesicle in rhomb porphyry (RP_1, Kolsås type). This find is in the middle of the lava flow. The coal blend is seen as globules ranging up to 2 cm in diameter, frequently veined by thin films of calcite which coat some conchoidal fracture surfaces in the coal blend. This veining has been noted in coal blend described from Semsvik, Asker by BUGGE and NEUMANN (1938).

The Mobråten specimen also reveals minute pockets of coal blend in the lava matrix and also small inclusions in the felspar rhombs which are now partially decomposed to calcite. This mode of occurrence has not been recorded in previous studies on coal blend. Coal blend from this specimen has been subjected to X-ray analysis using the powder method, but, as is common, no pattern was obtained.

Locality 3. At Skytebanen near Bergsmarka, Asker, a small valley descends from the rhomb porphyry plateau, which here is underlain by a thin bed of sandstone and the basalt flow (B_1). A vesicle collected from the basalt showed coal blend accompanied by calcite and quartz. Here the quartz coats the walls of the vesicle and it surrounds a core of calcite in which are embedded small globules of coal blend.

Locality 4. North of Semsvannet, at Hajum waterfall. The basalt (B_1) outcrops here exposing a red, oxidised top surface. It is riddled with calcite and quartz vesicles. Coal blend occurs surrounded either by calcite or quartz. Occasionally it will form complete vesicles.

In all specimens studied the coal blend has the same properties as those recorded for other occurrences in the Oslo region. It is developed as small, rounded masses, jet black in colour, having a markedly good conchoidal fracture, and frequently exhibiting a vitreous lustre.

Thin sections of the samples from localities 1, 2 and 4 have been examined. The coal blend appears as opaque anhedra with curved faces against the host mineral.

Microscopic examination of the Asdøl specimen shows the presence of small fanlets of a chlorite apparently replacing the calcite. Small granules of coal blend form a semi-continuous wall to the vesicle, in addition to its development in the centre of the calcite. The rhombs of felspar adjacent to the vesicle are fissured with small veins of coal blend.

In the thin section of the specimen from locality 2, coal blend is also seen to occur as small impregnations within the matrix of the rhomb porphyry.

J. A. Dons, who has kindly read this paper, informs me that since he wrote about coal blend (1956) he has visited new localities of this mineral and received from his colleagues information concerning several other finds. These are all situated within an area which has been affected by Permian hydrothermal activity (the Oslo region and the adjoining Precambrian areas).

Dons mentions particularly two localities in Precambrian gneiss. One occurs at Nesodden, 8 kilometres SSW of Oslo in a road section near the farm Skoklefall. The coal blend was to a great extent crushed by faulting and it appears mainly as large quantities of black dust together with calcite.

The other locality is at Bjordammen near Kragerø, about 25 kilometres SW of the Oslo region. Here coal blend, associated with calcite, has been found in gneiss. The coal blend fragment, 3 cm in diameter, was evidently a part of a greater mass.

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Manuscript received December 3, 1959.
Printed February 1960.

NOTISER

Det subkambriske peneplan i området Haukelifjell—Suldalsheiene

The sub-Cambrian peneplain of the area Haukelifjell—Suldalsheiene, central South Norway

AV

OLAV LIESTØL

Abstract. The author presents a isohypse map, equidistance 100 m, of the sub-Cambrian peneplain of Hardangervidda, central South Norway (Fig. 1). A more detailed map has been prepared for the southern part of the area (Fig. 2).

Det subkambriske peneplan over Hardangervidda og videre nordøstover til Hallingdal og Valdres er meget pent bevart. Det fremtrer som et særlig karakteristisk morfologisk trekk i landskapet.

Brøgger og Rekstad har i sine arbeider om Hardangervidda flere ganger behandlet denne gamle overflates høydeforhold og deformasjoner. Disse arbeider danner delvis grunnlaget for V. M. Goldschmidts kjente kart over det subkambriske peneplan i det sydlige Norge.

Peneplanet kan med sikkerhet bare påvises like i nærheten av grensene til fyllittområdene. Over den vestlige og nordlige del av Hardangervidda, hvor partier av fyllitt ligger noenlunde jevnt fordelt utover, blir derfor bestemmelsen ganske god. Her synes peneplanet dessuten å være påfallende jevnt, spesielt østover.

I vest har Rekstad foretatt høydemålinger av peneplanet. Han påviser flere mindre ujevnheter og forkastninger, bl. a. et langstrakt hvelv under Hallingskarvet og forkastninger i Måbødalens retning. Han nevner også peneplanets sterke skråning lenger sør, mellom Valldal og Sandfloeggi. Denne skråning ser man tydeligst i Trossovdalen, som går opp østover fra Valldalsvatn. Nederst i dalen ligger fyllitt. Ca. 1 km oppover dalen fra vatnet kommer grunnfjellet til syne igjen, og kan følges helt opp til den bratte kant av fyllitt med overliggende gneisgranitt øverst i dalen. Det område som Rekstad her nevner er den sydøstlige skråning av en langstrakt SV—NØ gående 500 m dyp depresjon i peneplanet. Det ser faktisk ut som dette er det urgamle anlegg til det dalsystem man i dag finner i Valldal, Røldal og Suldal.

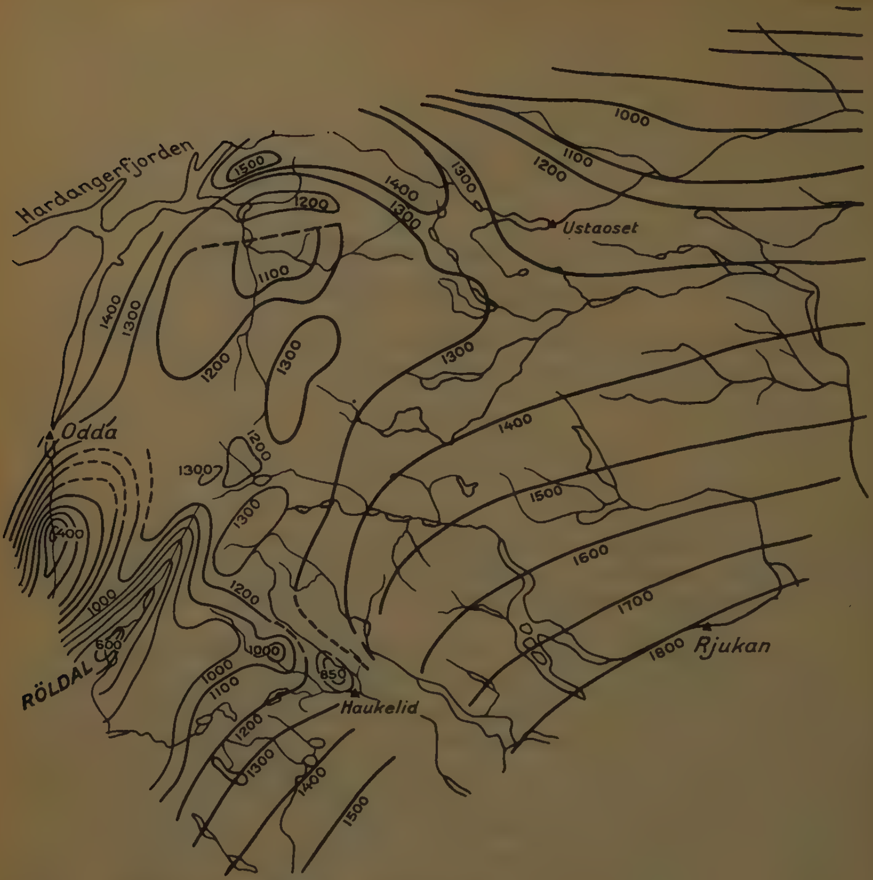

Fig. 1. Isohypsekart over det subkambriske peneplan over Hardangervidda. Ekvidistanse 100 m. *Isohypse map of the sub-Cambrian peneplain of Hardangervidda, central South Norway. Equidistance 100 m.*

Ennå større er depresjonen østenfor Odda. Fyllittens undergrense nede i depresjonen ligger 400 m.o.h., mens den like vestenfor går opp i over 1500 m.o.h.

Fig. 1 viser et isohypsekart med 100 m ekvidistanse over Hardangervidda og tilstøtende områder. Kartet er tegnet dels på grunnlag av eldre målinger, korrigert ved hjelp av nyere kart, dels på grunnlag av egne observasjoner.

Fig. 2 viser et område omkring Haukelifjellet som jeg har kartlagt mer detaljert. I motsetning til områdene i NØ og SV, er det her en sone som må ha vært utsatt for relativt store deformasjoner. Går man

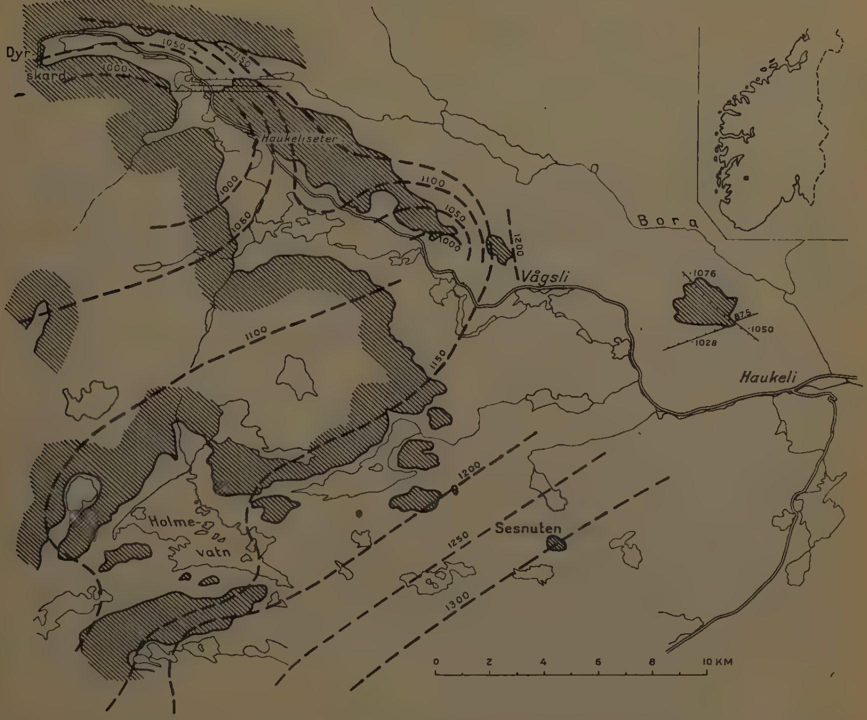

Fig. 2. Isohypsekart over det subkambriske peneplan i strøket Haukelifjell —Suldalsheiene. De skraverte områder er fyllitt. *Isohypse map of the sub-Cambrian peneplain in the area Haukelifjell—Suldalsheiene. The hatched areas are phyllite.*

langs veien østover fra Dyrskard ser man at peneplanet til å begynne med er ganske jevnt med en svak skråning mot SV. Ved nordenden av Ståvatn støter man på en rekke små Ø—V gående forkastninger, hvor sydsiden er sunket ned med tilsammen ca. 50 m. Herfra og østover er den gamle overflate til å begynne med horisontal, men stiger så jevnt fra Haukeliseter til Krekledyrskard. Stigningen er ca. 140 m på 4 km. Fyllitten er tildels blitt gnidd helt vekk, slik at den overliggende gneisgranitt har kommet helt ned i kontakt med grunnfjellet. Fra dette sted og videre østover er den gamle grunnfjellsoverflate sterkt deformert. Ved Raudberg, ca. 3 km vest for Vågslid, finner man f.eks. fyllitt i en høyde av 970 m.o.h., mens den i Vågslinuten 1 km østafor ligger på 1200 m.o.h. Langs fyllittgrensene har jeg observert skråninger av peneplanet med samme stigningsforhold. Man behøver derfor ikke postulere noen forkastning for å forklare høydedifferansen på peneplanet mellom Raudberg og Vågslinuten. Grunnfjellsoverflaten i dette felt er også i detalj meget ujevn. Små knauser av gneisgranitt stikker opp. På Vågslinuten er en kile av grunnfjellet skjøvet inn i fyllitten.

Den østligste utløper av fyllitt finner man på fjellet like nord for Haukeligrend. Det ser ut som om området er sunket eller foldet ned langs en NØ-SV-gående linje, som kommer markert frem på flybilder. I tillegg er den sørvestlige halvpart sunket ca. 80 m i forhold til den nordlige langs en NV-SØ-gående forkastning. Denne innsynkningen sammen med et mektig blåkvartsdekke, er sannsynligvis grunnen til at denne fyllitt-rest er blitt bevart.

Av kartet fig. 2 vil det fremgå at det subkambriske peneplan har beholdt sin form atskillig bedre lenger sørvest. Spesielt pent er det bevart i en 300 m bred horisontal hylle ca. 100 m over vestsiden av Holmevatn. Små forkastninger med vertikal forskyvning på noen desimeter finnes dog, noen steder med basalkonglomeratet bevart i forsenkningene. Sessnuten er det høyeste punkt hvor peneplanet kan bestemmes med sikkerhet. Det ligger her på 1300 m. Det er merkelig at denne fyllitt-rest er blitt bevart i så stor høyde på et sted hvor grunnfjellet omkring er så dypt ned-erodert.

Peneplanet stiger rimeligvis videre sydøstover, men da de kambrosiluriske fyllittrester helt mangler, kan man bare gjette seg til det videre forløp.

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Manuskript mottatt 20. november 1959.
Trykt februar 1960.

NORSK GEOLOGISK TIDSSKRIFT 40

Origin of Norwegian eclogites in gneisses

Paper read before the Geological Club of Bergen, October 10, 1959.

By
NIELS-HENR. KOLDERUP

ESKOLA's paper from 1921 is still the main source of our knowledge of eclogites in Norway. On this occasion I want to discuss the eclogites which occur in gneisses and leave those in peridotites, anorthosites etc.

Since the appearance of ESKOLA's paper, the ideas concerning the rocks in question have changed. The gneisses of the vast gneiss area of south-western Norway are supposed to be metamorphic rocks, formed through Caledonian processes of granitization. (BARTH 1939, O. HOLTEDAHL 1939.) Eclogites are also considered to be metamorphic rocks. The idea that igneous eclogites exist has been generally abandoned.

ESKOLA's opinion concerning the origin of the eclogitic inclusions in gneiss was expressed like this:

"The field-evidence so far gathered favours the opinion that the inclusions are no segregations crystallized within the gneiss magma, but more probably true fragments detached from larger bodies of eclogite-rocks."

The existence of such larger bodies or of fragments detached from them would substancially support this opinion.

The eclogites in gneisses dealt with by ESKOLA mostly occur north of Nordfjord. At present we know that a part of the northern coast of this fjord also belongs to the northernmost Cambro-Devonian syncline. If the eclogites are metamorphic rocks, there should be no principal difference between them and the garnet amphibolites which in many places resemble them very much. The only difference should be the degree of metamorphism. Thus the numerous bodies of garnet amphibolites, often called eclogite amphibolites, outcropping in the gneiss between the Bergen Arcs and the coastal syncline immediately north of the Sognefjord should have been formed in the same way as eclogites.

Recent field work financed by Norges almenvitenskapelige forskningsråd, has enlarged our knowledge concerning the Cambro- Devonian synclines on the coast of Sogn og Fjordane *fylke* (county) There are four synclines in connection with which occur three extensive bodies of basic rocks. These bodies are mainly surrounded by gneisses, more or less granitic. They are intersected by zones of granitic or gneissic rocks which hardly are to be explained as magmatic intrusive bodies. The surrounding gneisses generally contain inclusions or fragments of basic rocks in varying mineral facies.

The southern body is situated near the northern shore of Sognefjord, and east of the southern syncline. Its central part consists of norites or olivine norites. Some of these have an orbicular structure, with spheroidal orbicules measuring up to 1 m across. Diabase dykes, with a well recognizeable texture cut through them. This central part of the body exhibits a true igneous character. The marginal parts consist of saussurite gabbro or amphibolite. Even the saussurite gabbro locally displays an orbicular structure. Some small masses of titaniferous iron ore are found. Garnet amphibolites are very rare within this body.

The middle body of basic rocks extends along the southern border of the next syncline. Within this body there is some olivine gabbro, but the bulk consists of amphibolites, garnet amphibolites and eclogites. Here a giant crystal, measuring 90 cm, was found (N.-H. KOLDERUP and I. TH. ROSENQVIST 1950). Titaniferous iron ores occur. On its outskirts, especially to the west, this body passes gradually into migmatites. The basic rocks evidently were invaded by a granitic (or granodioritic) substance, forming schlieren, veins and larger bodies. To the east a smaller body of garnet amphibolite lies isolated in gneiss, in the same way as the inclusions of eclogite described by ESKOLA. It seems reasonable that this smaller body has been detached from the larger one.

The northern body of basic rocks is situated between the two middle synclines, on both sides of the Førdefjord. Within this body ordinary amphibolites, garnet amphibolites and true eclogites have been identified and previously described (N.-H. KOLDERUP 1928). Towards the east, this body gradually fades into gneiss. In some places there occur reaction rims along the contact between amphibolite and gneiss. For a distance of about 15 km, as far as the inner part of Førdefjord, we find isolated bodies of eclogite or eclogite amphibolite in the gneisses. These bodies are extensive, measuring several square kilometres near the main amphibolite body. The easternmost of them, however, are only some metres square. They occur in the same way as the eclogites north of Nordfjord, as described by ESKOLA. It seems most probable that these smaller bodies, mostly of eclogite amphibolite, are detached from the larger one, situated further west.

These three bodies of basic rocks, as well as the smaller ones supposed to be detached from them, are probably of the same origin. The Cambro-Silurian regions further south, especially south of Bergen, have extensive bodies of Caledonian gabbros, mostly saussurite gabbros. Thus it is reasonable to suppose that these three bodies also were

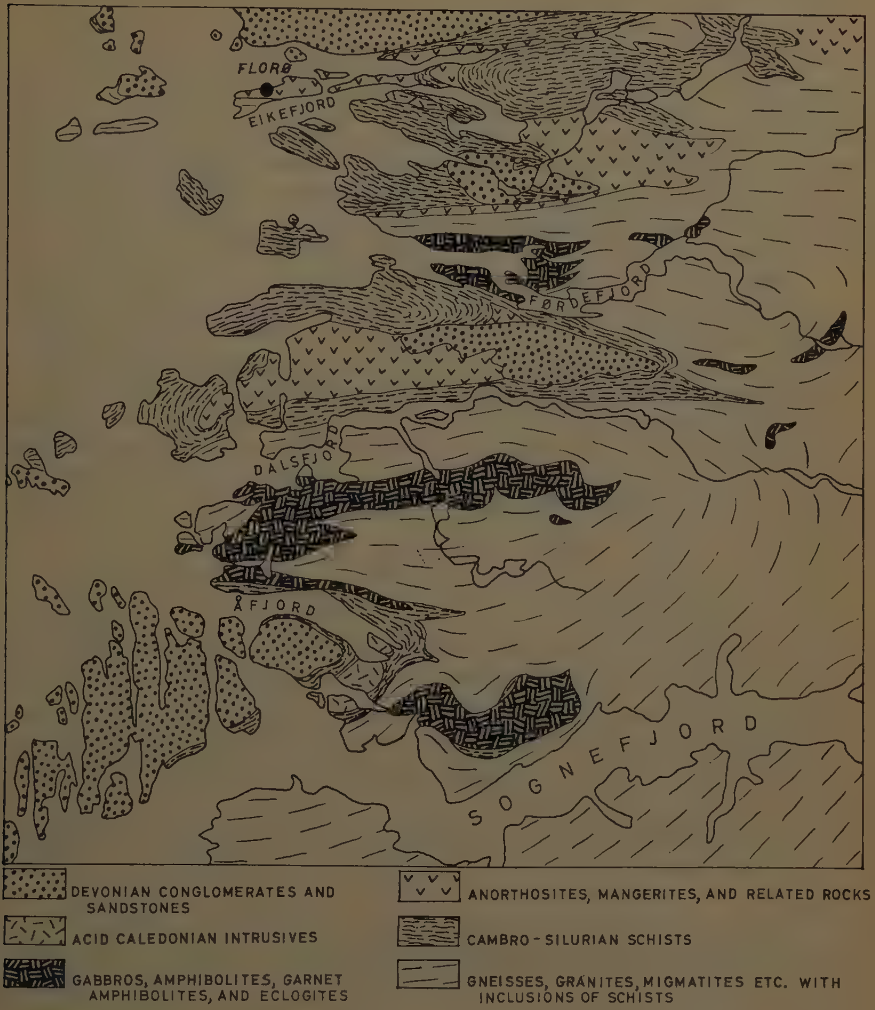
FLORØ
EIKEFJORD
FØRDEFJORD
DALSFJORD
ÅFJORD
SOGNEFJORD
DEVONIAN CONGLOMERATES AND SANDSTONES
ACID CALEDONIAN INTRUSIVES
GABBROS, AMPHIBOLITES, GARNET AMPHIBOLITES, AND ECLOGITES
ANORTHOSITES, MANGERITES, AND RELATED ROCKS
CAMBRO-SILURIAN SCHISTS
GNEISSES, GRANITES, MIGMATITES ETC. WITH INCLUSIONS OF SCHISTS

Fig. 1. Sketch map of synclines with gabbro etc. bodies in Sogn og Fjordane *fylke* (county), West Norway.

Caledonian igneous rocks, and that parts of the two northern ones were metamorphosed to eclogites or eclogite amphibolites. The smaller bodies of eclogite or eclogites amphibolite in the neighbourhood were detached from these larger bodies. Most likely also the other smaller bodies in gneiss in these regions were detached from these, or other larger bodies. In some cases the original body seems to be completely split up into such smaller inclusions in gneiss.

The inner part of this county, between Sognefjord and Nordfjord, has been more or less perfectly granitizised. A granite, probably of palingenetic origin, has previously been described from the inner end of Dalsfjord. (REUSCH 1880, N.-H. KOLDERUP 1928) Another one outcrops at the inner end of Førdefjord, and a third one has recently been found north of Nordfjord, in Stryn. But there are also numerous occurrences of garnetiferous mica schists, quartz schists and green hornblende schists within this gneiss and granite area. Their mode of occurrence indicates that they are relics that have survived the granitization.

It has repeatedly been found that inclusions do not exclusively consist of eclogite alone, but of eclogite and quartz schist or garnetiferous mica schists. From this it may be concluded that not only eclogites, but also neighbouring schists have survived the granitization. ESKOLA stated that the eclogite inclusions in gneiss generally have a marginal zone of garnet amphibolite, amphibolite or even rocks in a lower mineral facies. The writer's observations confirm this statement. The gneisses, generally with muscovite and epidote or zoisite, are in a lower facies than the eclogites. The processes that performed the granitization must have extended their influence into the marginal zones of the eclogites.

Investigations concerning the nature and origin, not only of the eclogites and gneisses, but also of the peridotites and anorthosites in this region have still to be carried out. It seems, however, justified to publish the results hitherto achieved. They may be thus summarized:

1. ESKOLA's statement, that the eclogites in the gneisses are true fragments, detached from larger bodies of eclogite rocks, is strengthened by the observations in and near the bodies of basic rocks here described.
2. The eclogites and eclogite amphibolites are metamorphic derivates of Caledonian gabbros or basalts.

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Manuscript received January 1960.
Printed February 1960.

NORSK GEOLOGISK FORENING

Møte nr. 383, 8. oktober 1959

Drammensveien 78, Oslo.

Tilstede 29 medlemmer og 8 gjester.

Møtet ble ledet av sekretæren.

Referat fra møte 382 ble opplest og godkjent. Referat fra geologisk ekskursjon til Tangenåsen 7/5 1959 ble opplest og godkjent. Forsamlingen mintes følgende medlemmer som var avgått ved døden siden forrige møte:

Dr. E. Jensen, Villavegen 3, Rjukan.
Cand. mag. E. M. Nørregaard, København.
Laboratorieingeniør Kr. Stenvik, Trondheim.

Som nytt medlem ble innvalgt:

443. Sivilingeniør Ole Petter Strand, Christiania Portland Cementfabrik, Slemmestad. Foreslått av B. Bruun og K. S. Heier.

Cirkulär nr. 1 fra IV Nordiska Geologiska Vintermötet ble opplest.

Det ble gitt en orientering om Mineralogisk Gruppe av Norsk Geologisk Forening som nå er dannet. Det ble opplyst om dato og foredragsholder for neste møte og dato for julemøtet.

Deretter ble ordet gitt til aftenens foredragsholder, cand. real. *Bjørn Andersen*, som fortalte om

«Istidsavsetninger på Sørlandet».

I ordskiftet etter foredraget deltok:

O. Holtedahl, W. Werenskiold, F. Isachsen, H. Rosendahl og foredragsholderen.

Møte nr. 384, 5. november 1959

Drammensveien 78, Oslo.

Tilstede 23 medlemmer og 13 gjester.

Formannen ledet møtet.

Referat fra møte nr. 383 ble opplest og godkjent.

Formannen ga en kort orientering om «XIIth General Assembly of the International Union of Geodesy and Geophysics som blir holdt i Helsinki, Finnland, 25/7—6/8 1960.

Som nye medlemmer ble innvalgt:

444. Cand. mag. Brynhild Steinvik Johannesen, Bygdøy Allé 8, 5. etg., Oslo. Foreslått av J. A. Dons og T. F. W. Barth.
445. Cand. jur. Solveig Bonde Ormestad, Bernh. Herres veg 19, Smestad. Foreslått av T. Strand og Kari Egede Larssen.
446. Dr. A. J. Rowell, Department of Geology, The University, Nottingham, England. Foreslått av A. Heintz og G. Henningsmoen.
447. Dr. André Prost, Laboratoire de Geologie du S.P.C.N., 12, rue Cuvier, Paris 5e, Frankrike. Foreslått av S. Skjeseth og F. Hagemann.

Aftenens foredragsholder var Dr. *Harald Carstens* som fortalte om «Sure vulkanitter omkring Trondhjemsfjorden».

I ordskiftet etter foredraget deltok T. Strand, H. Bjørlykke, B. Dietrichson, T. Barth, T. Gjelsvik, P. Holmsen, U. Havem, N. Spjeldnes og foredragsholderen.

BERGENS GEOLOGISKE KLUBB

Årsmelding for 1959

Møte nr. 72, 18. februar.

16 tilhørere.

Lektor *Isak Undås:* «Morene etter det senglaciale rastadium på sør-Vestlandet».

Møte nr. 73, 20. april.

20 tilhørere.

Professor dr. *Anders Kvale:* «Strukturundersøkelser i Gotthardområdet».

Møte nr. 74, 14. oktober.

16 tilhørere.

Professor dr. *Niels-Henr. Kolderup:* «Eklogittproblemet».

Møte nr. 75, 9. november.

24 tilhørere.

Professor dr. *Anders Kvale:* «Norske jordskjelv og deres forhold til tektonikk og postglacial landhevning».

25. november.

Medlemmene av Bergens Geologiske Klubb var invitert til N.I.F. Bergens avd. bygningsgruppe.

Foredrag av siviling. dr. *L. Bjerrum:* «Geotekniske problemer i forbindelse med den nye undergrunnsbanen i Oslo».

Møte nr. 76, 2. desember.

21 tilhørere.

Professor dr. *Anders Kvale:* «Orientering om utbygging av den seismologiske forskning i Norge og Norskehavsområdet». Demonstrasjon av jordskjelvstasjonens nye seismograf ved cand. real. M. Sellevold og cand. mag. S. Melkild. Etter foredraget enkel servering.

Møte nr. 77, 11. desember. Julemøte.

44 tilhørere.

Geolog *Odd Mortensen:* «På besøk hos Maharajaen av Chhota Udepur». Etter foredraget selskapelig samvær på Geologisk institutt.

Styret var i 1959:

Formann:	Professor Anders Kvale,
Viseformann:	Lektor A. Samuelsen,
Sekretær:	Amanuensis Ivar Hernes.

Nytt styre for 1960:

Formann:	Dosent Hans Holtedahl,
Viseformann:	Lektor Isak Undås,
Sekretær:	Vit. ass. Inge Bryhni.

THE MIDDLE ORDOVICIAN OF THE OSLO REGION, NORWAY

11. Pelecypoda.

By
HELEN and TRON SOOT-RYEN

With 4 plates and 1 figure in the text.

Abstract. The samples of Middle Ordovician pelecypods from the Oslo Region have been studied and 40 species are distinguished. The majority of them are referred to genera or families only, some are compared to species described from other regions and 7 species are described as new to science. The faunal assemblages, affinities and growth are discussed.

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Introduction and Acknowledgments.

The pelecypods from the Middle Ordovician of the Oslo Region have never been studied systematically. All we could find were a few scattered references in earlier papers. When Professor, Dr. Leif Størmer asked us to do what could be done with the samples, we hesitated, as we had no experience with Palaeozoic pelecypods and no reference collection was kept in the Palaeontological Museum of the University of Oslo. However, we agreed to do our best and the results are presented in this paper.

Very little has been published on the Middle Ordovician pelecypods from the Oslo region. So far, we have found only two papers where a few species are mentioned. Kjerulf (1865) reports *?Grammysia triangulata* Salter, from his etage 3, and *Modiolopsis nilssoni* Hisinger, from his etage 4, the last, however, is of Upper Ordovician age. Holtedahl (1909) mentions *Modiolopsis devexa* Eichwald, *M. attenuata* Eichwald, *Modiolopsis* sp. and *Arca* sp., mainly from the Cyclocrinus shale at Furuberget, Hamar. Unfortunately, we have not been able to locate these samples with certainty.

It has also been impossible to obtain several papers, which perhaps would contain descriptions of species unknown to us.

The material of pelecypods from the Middle Ordovician of the Oslo region is not very large as they never have been specially collected. It consists more or less of occasional samples from different localities. The material contains some 40 species and unidentifiable samples of pelecypods and certainly gives a very incomplete picture of the pelecypod fauna of the Norwegian Middle Ordovician. We have described 7 new species of pelecypods which we think are new to science and have tried to compare others with species described elsewhere. However, we are fully aware of the fact that new and better material may prove some of our results wrong. The larger part of the material consisted of badly preserved or incomplete casts which often made the determination a mere guesswork. Some specimens, however, could be studied more in detail, especially those kindly prepared by Dr. N. Spjeldnæs. We wish to express our heartiest thanks to Dr. Spjeldnæs for his valuable help and his never tiring assistance with literature and answering our many questions. For technical assistance with the manuscript and for answering an equal number of questions we want to thank Curator, Dr. G. Henningsmoen. We are indebted to Miss B. Mauritz and Mr. G. Brynhildsrud who have taken the photographs for the plates and to Miss I. Lowzow for drawing the textfigures. Dr. R. D. Morton has kindly corrected the English language. To Professor Dr. Leif Størmer who has given us all facilities and help, and made it possible for us to do this work, we wish to express our deepest gratitude.

Fortunately one of us had the opportunity to study the Hind collection and other samples of Ordovician pelecypods kept in the British Museum (Natural History), London. On the same occasion problems relating to the Norwegian material were discussed with Dr. L. R. Cox and Dr. S. Ware. Further Dr. David Nicol, then of U. S. National Museum, Washington D. C., kindly compared some of our samples especially of the family *Cyrtodontidae* with American material. We beg here to extend our best thanks to Dr. L. R. Cox, Dr. S. Ware and Dr. Nicol for their kind help and suggestions.

The abbreviation P.M.O. in the paper is a catalogue designation and stands for Palaeontological Museum, Oslo.

Systematical part.

Family Ctenodontidae Dall, 1895

Numerous Ordovician and Silurian species of this family have been described from various parts of the world. These species, which usually are referred to the genus *Ctenodonta* Salter, 1852 (= ? *Tellinomya* Hall, 1847), show several divergent lines of evolution and will certainly be referred to different genera in the future when more complete knowledge of the hinge characters are acquired. Prantl and Růžička (1954) have erected a new subfamily *Strabinae* with the genus *Straba* and subgenus *Strabina*, and Pfab (1943) has made the genus *Palaeoneilo* Hall, 1869, usually referred to the family *Nucula-*

nidae, a subgenus of the genus *Ctenodonta*. Species referred to the genus *Palaeoneilo* are recorded by Maillieux (1939) from the Ordovician of Belgium and by Hind (1910) from Girvan, Scotland, whereas this genus is generally considered to have been developed in Silurian times. Species listed under the genera *Nucula, Nuculana* (= *Leda*), or even *Arca*, all seem to be referable to family *Ctenodontidae*, as probably none of the families, to which the three above mentioned genera belong, had been differentiated in the Ordovician. However, though the family *Ctenodontidae* as used today is heterogenous, it seems advisable at present to refer all species with the typical taxodont hinge, without a distinct chondrophore, to this family.

Ulrich (1894) in his discussion of the genus *Ctenodonta* has placed the species in several groups named after the most typical species, combining hinge characters with form and sculpture of the shell. Many of the species described from north-east America show strong affinities to species from the Norwegian Ordovician, while the Bohemian species and also to some extent those from Great Britain are usually referable to other species-groups than most of the Norwegian forms. Isberg (1934) has described 6 species from Sweden which he refers to the *levata*-group and all seem to be rather different from the Norwegian species.

In some of the specimens we have studied, we have been unable to see the hinge characters. They are provisionally referred to the genus *Ctenodonta* on account of their general form. The majority of the specimens certainly belong to the *recurva*-group of Ulrich. We have had enough material to give a full description of two of these species, which we have named, while the others are referred to species A, B, etc. Species probably referable to other species-groups, but where we have been unable to see hinge characters, are, with one exception, only mentioned under the various species-groups. Other samples, which perhaps might belong to the family *Ctenodontidae*, are mentioned in the list of unidentifiable specimens.

Genus *Ctenodonta* Salter, 1852

Report Twenty-first Meeting British Association Advancement of Science, 1851, p. 63—64.

Type of genus: Tellinomya nasuta Hall, 1847.

Synonym: Tellinomya Hall, 1847.

Remarks: Though the name of Hall has the priority, *Ctenodonta* Salter, is now used by all palaeontologists. Salter introduced the generic name without species. There may be some nomenclatorial problems connected with the type species or specimen.

The *levata* group.

Ctenodonta nuda n.sp.

Plate I, fig. 1.

Material: Internal cast of one right and one left valve, P.M.O. nos. 38152 and 37861, from the Cyclocrinus beds, Furuberget, Hamar, Leg. J. Kiær 1896 and O. Holtedahl 1907.

Holotype: Internal cast of right valve, P.M.O. no. 38152.
Type locality: Furuberget, Hamar.
Type horizon: Cyclocrinus beds, 4b.

Diagnosis: Shell rather large, elongate ovate, broadly rounded anteriorly, tapering posteriorly ending in a narrowly rounded posterior margin, ventral margin convex. Umbones before the middle, projecting, incurved. Hinge line probably curved and the dorsal margin posterior to the beaks, concave. Hinge not observable. Adductor muscle scars distinct, the anterior scar placed near and above the middle of the anterior margin. The posterior scar large, elongate, placed obliquely from a little below the middle of the posterior margin to the hinge margin dorsally, leaving a free margin as broad as the scar itself posteriorly. Both scars bordered on the inside by distinct, rather deep crests. Length 15 mm, height 10.5 mm, semidiameter 4 mm.

Remarks: This species is in several respects like *Ctenodonta albertina* Ulrich, 1894, also figured by Foerste (1924, pl. XVI, figs. 7a, b, c). The posterior end is, however, narrower and the anterior adductor is placed lower than in *C. albertina.* Though the hinge could not be studied, we think this species is so distinct that it should be given a name, especially since *C. albertina* Ulrich is recorded from the Upper Ordovician only, where it is stated to be common in the upper beds of the Cincinnati group, Waynesville formation. Our species may also be compared to *Ctenodonta coreanica* Kobayashi, 1934. The outline of both is nearly the same, but Kobayashi's species has much smaller posterior adductor scar.

The *logani* group

Ctenodonta? species A

Plate I, fig. 2.

Material: Internal cast of one right valve, P.M.O. no. 33245, from between quay and Hofstangen, Gran, Hadeland, Ogygiocaris shale, 4aα. Leg. O. Holtedahl.

Description: Shell small, elongate, subovate, gibbous, with the umbones a little behind the middle. Umbones large, inflated and incurved. Anterior end the longer and narrower than the shorter more broadly rounded posterior end. Anterior adductor scar placed dorsally near the anterior end, posterior adductor scar also dorsal but nearer the beak than the posterior end; pallial line simple, close to the margins. Length 5 mm, height 3.5 mm.

Remarks: This specimen is with doubt referred to the genus *Ctenodonta*, but it bears resemblance to *C. logani* Salter, 1859. Kobayashi (1934) has described *C. corbuliformis*, a species which seems to be closely related.

The *recurva* group.

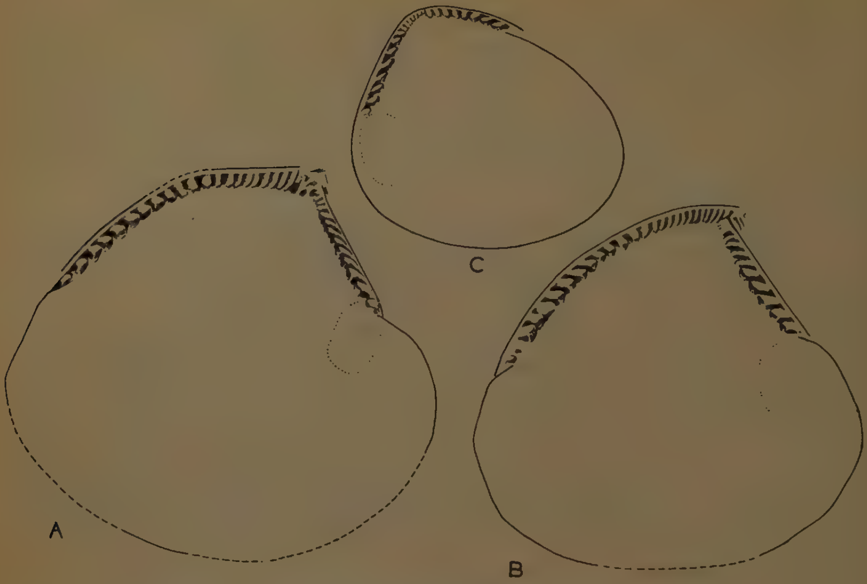
Species of this group seem to be rather common in the Middle Ordovician of the Oslo region. Several closely related species have been described and some are difficult to recognize without actual specimens for comparison. The sculpture, the number of concentric lines on 2 mm in the middle of the valve, seems to be a fairly good character together with form and the hinge wherever that could be studied. We have named two species, which are thought to be undescribed, but we are aware of the possibility that they might be conspecific with some species described earlier. However, we think that these two species based on a fair amount of material can be recognized when found on other localities and that the names will be useful for reference. Other species, of which we have had one specimen only or unsufficient material, are not given new names even if we think that some of them represent undescribed species.

Ctenodonta spjeldnaesi n.sp.

Plate I, figs. 3—6, textfig. 1.

Name: The specific name is in honour of Dr. Nils Spjeldnæs.

Material: 15 specimens and casts, P.M.O. nos. 8277, 40307, 40308, 40309, 40310, 40311, 40313, 40314, 40315, 40316, 40317, 40318, 40319,



Textfig. 1. *Ctenodonta spjeldnaesi* n.sp. Hinges.
A: — P.M.O. no. 40313.
B: — P.M.O. no. 40315.
C: — P.M.O. no. 40314, a young specimen.

from Vestbråten, Ringerike, Upper Chasmops shale, 4bγ. Leg. J. Kiær, 1922, L. Størmer, N. Spjeldnæs, S. Skjeseth, 1955. 8 specimens and casts, P.M.O. nos. 7255, 7306, 7307, 7309, 7310, from western side of Røysetangen, Ringerike, Chasmops shale, 4b. Leg. J. Kiær, 1913.

Holotype: One left valve, P.M.O. no. 40308.
Type locality: Vestbråten, Ringerike.
Type horizon: Upper Chasmops shale, 4bγ.

Diagnosis: Shell small, rounded triangular, slightly longer than high. Umbones full but not much inflated, opisthogyre. Umbonal angle blunt. Anterodorsal margin curved and inflected with a more or less distinct anteroventral angle, ventral margin rounded and posteroventral corner broadly rounded. Posterodorsal margin concave to straight with the lower part somewhat protruding. Parallel to the anterodorsal margin there is a more or less distinct sulcus. Sculpture consisting of somewhat irregular concentric lines with broad interspaces, 5—6 lines on 2 mm in the middle part of the valve. On the internal casts there are several growth lines along the margins. Hinge teeth in two series (textfig. 1), c.9 proximal anterior teeth, lamelliform and nearly vertical to the hinge margin. 14 distal teeth larger, angular and more oblique to the hinge margin. Proximal posterior teeth short, about 3—5, distal 8 teeth large obliquely set and angulated. The region beneath the umbo is not complete, but there seems to be a flat or slightly concave part just where the two series of teeth meet. The anterior adductor scar is elongate and placed rather low, the posterior adductor scar distinct, ovate and placed below the distal tooth. Pallial line entire. Length 13.2 mm, height 12.6 mm, semidiameter c. 2 mm.

Remarks: This species which is somewhat variable is very common in the Middle Ordovician of Ringerike. Making due allowance for variation we think that the specimens from both localities can be referred to one species. The specimens from Røysetangen are slightly larger than those from Vestbråten, with a maximum height of 14,7 mm.

C. spjeldnaesi n.sp. resembles *C. recurva* (Ulrich, 1892) and *C. intermedia* (Ulrich, 1892), which both have 5—7 concentric lines on 2 mm and which have approximately the same form. The hinges of these species are furnished with more numerous teeth and the postero-dorsal corners are slightly different. *C. similis* (Ulrich, 1892) has finer concentric sculpture and distinctly smaller teeth towards the proximal part of the series. The new species is also closely related to *Nucula varicosa* Salter, 1854, of Hind (1910), which seems to comprise more than one species. Lamont (1946) has described a large similar species, *Nucula magna* which also is closely related to *C. spjeldnaesi*, and Reed (1952) has named a related species *C. perangulata*. In spite of this we think that our species is different from both the American and the British species. Until a thorough revision of all species of the *recurva*- group has been made it seems correct to keep the Norwegian species separate.

Text fig. 1c shows the form and hinge of a small specimen of the same species.

The flat part below the meeting point below the two series of teeth could support a small resilium, but it is more than doubtful that the ligament had separated into an external and internal part as early as Ordovician times. On the other hand, species of the *recurva* group could probably be the ancestors of species of the genus *Nucula* and related genera.

Ctenodonta norvegica n.sp.

Plate I, figs. 7—8.

Material: Casts of 6 specimens, P.M.O. nos. 6572, 6573, 6574, 6575, and moulds P.M.O. nos. 6570, 6571, from Langåra, Asker, 4bβ. Leg. J. Kiær, 1920.

Holotype: Left valve, P.M.O. no. 6572.
Type locality: Langåra, Asker.
Type horizon: Lower Chasmops limestone, 4bβ.

Diagnosis: Shell small, rounded triangular, height and length nearly equal. Umbones full, slightly opistogyre, umbonal angle a little larger than 90°. A shallow sulcus extends from the beaks to the anteroventral corner. Anterodorsal edge narrowly flattened. Anterodorsal margin convex ending in a rounded anteroventral corner, continuing in the convex ventral margin, which passes over to the slightly convex posterior and posterodorsal margins in a broadly rounded posteroventral corner. Sculpture consisting of raised, close set, slightly irregular concentric lines, interspaces broader than the lines. In the middle of the valve there are about 13—14 concentric lines on 2 mm. Hinge with teeth in two series separated in the umbonal angle. The proximal posterior teeth lamelliform, rather elongate and not angulated, about 10 teeth to be counted (P.M.O. no. 6574). Pallial line and muscle scars not observed. Length 9.5 mm, height 9.5 mm, semidiameter c.2 mm.

Remarks: This species undoubtedly belongs to the *recurva* group, though the posteror margin is slightly convex. The hinge, of which a part could be seen, resembles that of *C.spjeldnaesi* n.sp. The most marked character which distinguishes this species, is the numerous and fine concentric lines. The sculpture resembles *C.compressa* (Ulrich, 1892), which, however, has a more acute umbonal angle, about 85°, concave posterodorsal margin and narrower beaks. Some specimens in the Hind collection labelled *Nucula varicosa* Salter, 1854, are like our species, but apparently the samples of *N.varicosa* contain more than one species.

A left valve P.M.O. no. 6573, from the same locality is a smaller, narrower and more inflated specimen, height 5 mm, with about 12 concentric lines on 2 mm (plate 1, fig. 8). As this specimen perhaps falls within the range of variation of *C.norvegica* it seems unadvisable to name it until more material proves it a distinct species.

Ctenodonta species B.

Plate I, fig. 9.

Material: One small left valve and part of the ventral side of a larger specimen, P.M.O. no. 5846, 5848, Ostøya, Bærum, 4bβ. Leg. Th. Vogt, 1908.

Description: The small specimen, height 4 mm, shows an umbonal angle of about 90° with straight cardinal margins, narrow pointed beak, and irregular concentric sculpture, about 9—10 lines on 2 mm. The hinge shows a few lamellar teeth of the same type as observed in *C.spjeldnaesi*. The larger specimen apparently belongs to the same species.

Ctenodonta species C.

Plate I, fig. 10.

Material: One right valve, P.M.O. no. 35332, S. of Gran, Hadeland, Upper Middle Ordovician. Leg. O. Holtedahl, 1916.

Description: This specimen resembles species B but is apparently different. The valve is about 7 mm high, and has 10—11 regular concentric lines on 2 mm, a distinct posterior fold and a flattened posterodorsal margin.

Ctenodonta species D.

Plate I, fig. 11.

Material: Part of a valve P.M.O. no. 58265, S. of Røykenvik, Hadeland, 4bβ-γ. Leg. T. Strand, 1933.

Description: This specimen seems to be related to *C.spjeldnaesi*. There are about 7 concentric lines on 2 mm but the form seems to be different. The height is about 5.5 mm.

Ctenodonta species E.

Plate I, fig. 12.

Material: One left valve, P.M.O. no. 33835, S. of Røykenvik, Hadeland, Chasmops limestone, 4bβ. Leg. O. Holtedahl.

Description: This specimen belongs to a species different from any of those previously mentioned. The form is broadly triangular-ovate with curved anterodorsal margin, slightly convex posterodorsal margin and an evenly rounded ventral margin. The beak is rather narrow and the umbonal angle is blunt. The most conspicuous character is the presence of distinct concentric lines, about 4 on 2 mm, irregularly spaced and with broad interspaces. There is a distinct posterior depression from umbo broadening towards the posteroventral margin. Hinge and muscle scars not seen. Length c. 12.5 mm, height 11 mm, semidiameter c. 2 mm.

Remarks: This species is with some doubt referred to the *recurva* group. The more ovate form and wide umbonal angle indicate that it could be placed in another group, but so far we have been unable to trace species closely resembling the specimen at hand.

Ctenodonta? species F.

Plate I, fig. 13.

Material: Internal cast of one left valve, P.M.O. no. 37861, Furuberget, Hamar, Cyclocrinus beds, 4b. Leg. J. Kiær, 1896.

Description: This small ill-preserved specimen is with doubt referred to the genus *Ctenodonta,* as neither the hinge nor the muscle scars could be seen. The form is triangular with a slightly concave posterior margin and a curved anterior margin, the ventral margin is convex with narrowly rounded corners. The height and length are a little more than 5 mm.

Remarks: There is some resemblance to *C.compressa* (Ulrich, 1892).

The *nasuta* group.

Ctenodonta? species G.

Plate I, fig. 14.

Material: A poorly-preserved cast of a right valve, P.M.O. no. 8222, Ringsås, Ringerike, Upper Chasmops limestone, 4bδ. Leg. O. Holtedahl, 1912.

Description: This worn cast is with doubt referred to the genus *Ctenodonta* and to the *nasuta* group. It is elongate ovate, tapering towards both ends with subcentral prosogyre umbones. Hinge and muscle scars not seen. Length 9.5 mm, height 5 mm.

Remarks: The specimen resembles to some extent *C.*aff. *transversa* (Portlock, 1843) of Hind (1910, pl. III, fig. 12), *C.carpenderi* Schuchert, 1900 and *C. subnasuta* Ulrich, 1894 of Schuchert, 1900.

Ctenodonta? species H.

Plate I, fig. 15.

Material: P.M.O. nos. 35331, 35333, 35334, S. of Gran, Hadeland, Upper Middle Ordovician. Leg. O. Holtedahl, 1916.

Description: Several internal casts of an elongate ovate species with large submedian umbones are with doubt referred to this genus. The ventral margin is but little curved, and the two ends are either narrowly rounded or semitruncate. Hinge and muscle scars not seen. Surface apparently with concentric sculpture. The shells seem to have been rather inflated. Maximum length 11.5 mm.

Remarks: These specimens are apparently more elongate than species G but may be compared to the same species as that species. They also bear a resemblance to *C.oblongata* Kobayashi, 1934.

Species group?
Ctenodonta species I.

Plate I, fig. 16.

Material: Three internal casts and three moulds, P.M.O. nos. 69558, 69559, 59660, 69561, 69564(?), from the section at Hvalstad, Asker, 4bγ, lower part. Leg. N. Spjeldnæs, 1957.

Description: Shell small, elongate, inequilateral, with slightly convex and subparallel dorsal and ventral margins, broadly rounded anterior and posterior margins, perhaps the posterior margin can be said to be subtruncate in some specimens. Umbones small, prosogyre, not projecting, placed before the middle of the valve. Greatest convexity in the middle of the valve, flattening out posteriorly, but bordered anteriorly by a shallow concavity. There seems to be a short lunule. Posterior cardinal margin nearly straight and 6 small teeth can be observed there. Muscle scars indistinct but placed near the dorsal margin. No sculpture visible. Length 6 mm, height 3.2 mm.

Remarks: This species also comes close to *C. transversa* (Portlock, 1843) and especially to the species figured by Hind (1910, pl. III, fig. 12) as *C.* aff. *transversa* (Portlock).

Ctenodonta species K.

Plate I, fig. 17.

Material: Internal casts of three right valves, P.M.O.nos. 40324, 69562, 69563, from roof of tunnel, W. of Billingstad, Asker, 4b*a*. Leg. N. Spjeldnæs, 1958.

Description: Shell medium sized, ovate, inequilateral with umbones in the anterior third. Anterior margin with a slight concavity before umbo (lunule), semicircularly rounded, ventral margin convex, posterior margin broadly rounded, dorsal margin nearly straight but without a posterodorsal corner. Umbones small, prosogyre. Shell rather flat and evenly curved without visible sculpture or muscle scars. Posterior cardinal margin with traces of 6—7 small teeth on one of the specimens. Length 9.5 mm, height 5.7 mm.

Remarks: These specimens are rather unlike species of the genus *Ctenodonta*. The outline resembles more some species of the genus *Cleidophorus* Hall, 1847, than *Ctenodonta*. The specimens may be compared to *C.transversa* (Portlock, 1843) or to *C.deserta* Reed, 1952 though both species are lower and have more central umbones.

FAMILY CYRTODONTIDAE ULRICH, 1894

Several internal casts can be referred to one or another of the genera of this family. Though no complete hinge could be studied, the ventricose form of the valves and the characteristic median keel indicate that some casts at least, may belong to species of the genus *Cyrtodontula* Tomlin, 1931. Some casts have a dark film on the surface, a character which according to Ulrich (1894) should indicate the family *Modiolopsidae*. Foerste (1924, p. 151) mentions, however, a black film on specimens of *Whitella*. The ventricose form of most of the casts from Norway is, however, quite unlike species of the family *Modiolopsidae*. Two specimens are with some doubt referred to the genus *Vanuxemia* Billings, 1858.

Many different species have been described from eastern North American Lower Trenton to Middle Richmond, more common in the younger strata; and several species are recorded from the British Ordovician. Isberg (1934) describes one species of *Cyrtodontula* Billings, 1858 from the Leptaena limestone in Sweden.

Genus *Cyrtodontula* Tomlin, 1931.
Proc. Malac. Soc. London, vol. 19, p. 175.

Synonym: Whitella Ulrich, 1890, American Geologist, vol. VI, p. 176, not of Spinola, 1850.

Type of genus: Whitella obliquata Ulrich, 1890.

Remarks: Species of this genus seem to be the most common pelecypods in the Middle Ordovician of Norway. Especially the Chasmops shale of Røysetangen, Ringerike, contains many specimens. We have described one species as new to science but consider some closely related specimens to belong to other species.

Of the measurement used for specimens of this family, height indicates the largest measurement from the umbo to the posteroventral margin while breadth indicates the maximum measurement between the anterior and posterior margins.

Cyrtodontula dubia n.sp.
Plate II, figs. 18—20.

Material: 8 internal casts or parts of casts and 3 parts of moulds, P.M.O. nos. 7254, 7256, 7296, 7297, 7299, 7301, 7303, 7304, from western side of Røysetangen, Ringerike, 4b. Leg. J. Kiær, 1913.

Holotype: Internal cast of a left valve, P.M.O. no. 7254.

Type locality: Western side of Røysetangen, Ringerike.

Type horizon: 4b.

Diagnosis: Shell rather large, elliptical, rather inflated, diameter nearly equalling the breadth of the valves. Anterior margin expanded, curved to the semicircular ventral margin, which continues in the curved and expanded posterior margin. Dorsal margin and hinge line rather short. Umbones large and curved, prosogyrous, umbonal ridge prominent, rounded, greatest convexity in the anterior third of the valve. The anterior slope is convex, the posterior slope concave. Sculpture consists of irregular concentric lines especially distinct along the margins. Anterior adductor scar indistinct, placed just in front of the beaks, posterior adductor scar not observed. Hinge unknown, except for the two semiparallel ridges on the dorsal part of the posterior margin. The holotype has a height of 33 mm, breadth 25 mm, semidiameter 12 mm; largest cast has a height of about 48 mm.

Remarks: This species resembles *Whitella megambona* Whitfield, 1877, but the posterior margin is more expanded anteriorly and the dorsal slope is distinctly concave. Though all specimens are internal casts and the moulds are defective, we find that this species should be given a specific name as it apparently is very common in that particular horizon.

Cyrtodontula species A.

Plate II, fig. 21.

Material: Internal cast of one left valve, P.M.O. no. 7287, Chasmops shale from western side of Røysetangen, Ringerike, 4b. Leg. J. Kiær, 1913.

Description: This specimen is apparently narrower than *C. dubia* n.sp. and has a more angulated umbonal ridge and a flat posterior slope. It might, however, be an extreme variation of *C. dubia*. Height 48 mm, breadth about 27 mm.

Cyrtodontula species B.

Plate II, fig. 22.

Material: Internal casts of 4 defective valves. P.M.O. no. 20614, from Bratterud, Ringerike, 4bα. Leg. J. Kiær, 1913.

Internal cast of a defective left valve, P.M.O. no. 7295 from western side of Røysetangen, Ringerike, 4b. Leg. J. Kiær, 1913.

Description: These specimens are of a much broader form than *C. dubia*. The Bratterud specimens are very gibbous and measure: height 41 mm, breadth 29.5 mm, semidiameter 16 mm, while the specimen from Røysetangen is less inflated. All specimens have a convex posterior slope. Perhaps these specimens should be referred to the genus *Vanuxemia* Billings, 1858, or *Cyrtodonta* Billings, 1858.

Cyrtodontula aff. *complanata* (Foerste, 1914).

Plate II, figs. 23—26.

Whitella complanata Foerste: Bulletin Science Laboratory Denison University, vol. 17, p. 300, pl. 1, fig. 2.

Material: One cast of a left valve, P.M.O. no. 7288, from western side of Røysetangen, 4b. Leg. J. Kiær, 1913.

One internal cast of a right valve, P.M.O. no. 40306, from western side of Røysetangen, 4b. Leg. J. Kiær, 1913.

One defective cast of a right valve, P.M.O. no. 20644, from Vestbråten, Ringerike, 4b. Leg. J. Kiær, 1920.

One cast of a right valve, P.M.O. no. 7810, from above Vestbråten, Røyse, Ringerike, 4bγ. Leg. J. Kiær, 1920.

? One cast of a right valve, P.M.O. no. 7251, from western side of Røysetangen, Ringerike, 4b. Leg. J. Kiær, 1913.

? One deformed cast of a left valve, P.M.O. no. 20592, from Bratterud, Ringerike, 4bα. Leg. J. Kiær, 1913.

Description: These casts seem to belong to one species though the two last mentioned casts are with doubt included here. All have a widely expanded posterior wing with a rounded posterodorsal corner. The casts usually have a blackish covering and many irregular concentric growth-lines. The umbonal ridge descends steeply anteriorly from the highest crest of the umbonal ridge, and with the slope nearly flat, while the flattish posterior slope forms an angle of about 45° with the sagittal plane. Specimen no. 7251, pl. II, fig. 25 is small with a rounded umbonal ridge and three sharp concentric steps, and specimen no. 20592, pl. II, fig. 26, is much more elongated than the rest of the specimens and should perhaps be referred to another species.

Remarks: All these specimens seem to be related to *C.complanata* (Foerste), but probably not identical with that species.

Cyrtodontula species C.

Plate II, figs. 27—28.

Material: Internal cast of one complete specimen, P.M.O. no. 37528, from the railway cutting at Furuberget, Hamar, Mastopora zone, 4bβ. Leg. J. Kiær, 1907.

Description: This small specimen has very large, prosogyre umbones, the umbonal ridge is angular, rather sharp dorsally, becoming rounded to obsolete ventrally with a steeply descending slope posteriorly. The anterior wing has an angulated corner, while the anterior margin, which is nearly parallel to the posterior margin, is slightly convex. The sculpture consists of traces of concentric lines. Height 12.5 mm, breadth 9 mm, diameter 8.5 mm.

Cyrtodontula aff. *subtruncata* (Hall, 1847).

Plate II, figs. 29—30.

Palaeontology of New York, vol. I, p. 156, pl. XXXIV, fig. 9, pl. XXXV, fig. 3a, b, c.

Material: Internal cast of one specimen, P.M.O. no. I 762, from Gullerud, Ringerike, 4aβ. Leg. J. Kiær, 1915.

Description: Shell rather large, inflated, elongate, with anterior umbones, dorsal and ventral margin slightly divergent with the greatest height posteriorly, closed. Anterior margin nearly straight, anteroventral corner rounded, ventral margin almost straight, posterior margin including ventral and dorsal corners semicircular, dorsal margin straight. Umbones inflated and strongly curved, prosogyre. Lunule apparently small. Umbonal ridge strong, rounded, becoming obsolete near the margin, median part of the valves more or less flat. Sculpture visible on a part of the dorsal side of the umbonal ridge where it consists of fine, closely set concentric lines. There are also some coarser growth lines. Anterior adductor scar elongate, placed along the anterior margin. Hinge unknown. Heigth 36 mm, breadth 24.5 mm, diameter 22 mm.

Remarks: This specimen is very like the figure of Hall (1847, pl. XXXV, fig. 3a, b) of his *Edmondia subtruncata* described from the upper part of the Trenton limestone. It has also the fine concentric sculpture of that species. But as the specimen is slightly distorted and the part between the beaks could not be seen, we are not certain that it is a real *C. subtruncata*.

Cyrtodontula species D.

Plate III, figs. 31—32.

Material: Internal cast of one specimen, P.M.O. no. 20593, from Bratterud, Ringerike, 4bα. Leg. J. Kiær, 1913.

Description: Shell medium sized, not much inflated. The anterior margin forms an angle of about 90° with the dorsal margin which is slightly convex, ventral margin semicircular ending in a blunt angle towards the straight descending posterodorsal margin. Umbones not much inflated and umbonal ridge rounded, becoming obsolete ventrally. An umbonal sulcus well developed. Anterior muscle scar short, ovate, placed in the middle between the umbo and the anterodorsal corner. Blackish remains of the shell are seen in some places. Height 25 mm, breadth 18 mm, diameter 10.8 mm.

Remarks: This specimens is less gibbous than the preceding species and is in this respect more like the next two species.

Cyrtodontula cf. *compressa* (Ulrich, 1890)

Plate III, fig. 33.

Whitella compressa Ulrich: American Geologist, vol. VI, p. 180. Fig. in Ulrich 1894, pl. XLI, figs. 6—9.

Material: Internal cast of a left valve, P.M.O. no. 30978, from Frognøya, Ringerike. Tretaspis limestone, upper part, 4c. Leg. T. Strand, 1932.

Description: This specimen has the same broad and flat form as *C.compressa* (Ulrich). Anterior margin forms a rounded corner with the dorsal margin and projects beyond the beaks, descending in a sligth curvature, joins the rounded ventral margin without an anteroventral corner. The posterior margin forms an angular narrowly rounded corner and continues nearly in a straight line towards the umbones. The umbonal ridge is low and disappearing towards the ventral margin. The anterior slope is slightly convex, the posterior slope slightly concave. Anterior adductor scar ovate and placed in the anterodorsal corner, the posterior adductor scar elongate and placed inside and ventral to the posterodorsal corner. Pallial line entire and distinct. Height 18 mm, breadth 15 mm, semidiameter 3.5 mm.

Remarks: Whitella compressa Ulrich is recorded form the middle third of the Trenton shales, Minneapolis and St. Paul, Minnesota. The characters of the Norwegian specimen agree nearly completely with the description and could perhaps be referred to the Trenton species without reservation.

Cyrtodontula species E.

Plate III, fig. 34.

Material: Internal cast of a left valve, P.M.O. no. 8267, from Juern below Frok, Ringerike, Lower Chasmops limestone, 4bβ. Leg. J. Kiær, 1920.

Description: Shell broad, ovate, anterior margin broken dorsally. Umbonal ridge rather sharp, steeply descending anteriorly where the slope is concave, posterior slope convex to slightly concave. Umbones rather pointed, prosogyre. Largest convexity in the anterior third. The impression of one lateral tooth bordered by two ridges is seen on the dorsal part of the posterior margin. Anterior adductor scar partly preserved on the anterodorsal part, pallial line entire. There are 3—4 concentric growth-lines and two short radiating lines on the anterior side of the umbonal ridge nearest the ventral margin. Height 17.5 mm, length 13.5 mm, semidiameter c. 4.7 mm.

Genus *Vanuxemia* Billings, 1858

Report of Progress Geological Survey of Canada, 1858, p. 186.

Type of genus: Vanuxemia inconstans Billings, 1858.

Remarks: One internal cast and one mould are with some doubt referred to this genus as the site of the anterior adductor could not be seen.

Vanuxemia? species A.

Plate III, fig. 36.

Material: Internal cast of a right (?) valve, P.M.O. no. 7302, from western side of Røysetangen, Ringerike, 4b. Leg. J. Kiær, 1913.

Description: Shell ovate, strongly inflated. Ventral margin semicircular, anterior and posterior margins defective in the dorsal parts. Umbones narrow, pointed, and strongly incurved, umbonal ridge rounded with nearly flat slopes, slightly convex anteriorly and a little concave posteriorly. Muscle scars and hinge not observable. Sculpture absent. Heigth 25 mm, breadth 20 mm, semidiameter c.9.5 mm.

Vanuxemia species B.

Plate III, fig. 37.

Material: One external mould and latex cast of left valve, P.M.O. no. 40305, from western side of Røysetangen, Ringerike, 4b. Leg. J. Kiær, 1913.

Description: Shell obliquely ovate, umbones nearly anterior, projecting, incurved and prosogyre. Anterior end narrowly rounded and short. Anterior margin curved and continues in the semicircular ventral margin, posteroventral corner rounded. Umbonal ridge low and broadly rounded. Sculpture consists of numerous fine and regular concentric lines and 5—6 step-like growth-lines. Hinge and muscle scars not observable. Greatest height 22 mm, breadth 17 mm, semidiameter 6 mm.

Remarks: This specimen has the form of *Vanuxemia decipiens* Ulrich, 1894, and the less inflated shell resembles *Vanuxemia wortheni* (Ulrich, 1888). However, we do not refer our specimen to either of them as we have not seen the hinge and the anterior adductor scar. The sculpture may also be different.

? Cyrtodontidae sp.

Plate III, fig. 35.

Material: Internal cast of one specimen, P.M.O. no. 7252, from Røysetangen, Ringerike, Chasmops shale, 4b. Leg. J. Kiær, 1913.

Description: Shell ovate, anterior margin curved continuing in the rounded ventral margin which runs without an angle to the slightly curved to straight posterior and cardinal margins. Beaks anterior, umbo narrow with a sharply angular umbonal ridge with nearly flat slopes. The anterior part between the beaks are defect. Nothing could be seen of the hinge. There seems to be a distinct anterior adductor scar just in front of the beaks, and two small accessory scars on top of umbo. Sculpture consists of broadly spaced growth-lines. The valves are closed. Height 20.5 mm, breadth 14 mm, semidiameter 4.6 mm.

Remarks: This specimen probably belongs to the family *Cyrtodontidae* but we have been unable to refer it to a genus or to trace species resembling it. The distinct anterior adductor scar also points to the family *Modiolopsidae*, but the other characters apparently do not agree with that family.

FAMILY AMBONYCHIIDAE MILLER, 1889

Several casts are referable to this family. The hinge and muscle scars could not be studied, but the form of the casts indicates that most of them can be placed in the genera *Ambonychia* Hall, 1847, *Ambonychinia* Isberg, 1934, and *Clionychia* Ulrich, 1892. Many of the species referred to these genera are established on very vague characters and resemble each other closely. We have, however, tried to compare some of the casts to species known from other regions, but have made no attempts to describe them as new species. The best preserved casts are figured and given a short description. The measurement "height", is also for this family taken between the umbo and the posteroventral margin.

Genus *Ambonychia* Hall, 1847

Palæontology of New York, vol. I, p. 163.

Type of genus: *Ambonychia bellistriata* Hall, 1847.

Remarks: The question *Ambonychia* Hall, 1847, versus *Ambonychinia* Isberg, 1934, is not yet solved. We have, however, followed the view of Reed (1952) and placed species without a radial sculpture in the genus *Ambonychinia* and used Hall's genus for the radially striated species.

Ambonychia aff. *orbicularis* Hall, 1847

Plate III, fig. 38.

Ambonychia orbicularis Hall: Palæontology of New York, vol. I, p. 164, pl. XXXVI, figs. 5a, b, c, d.

Material: One broken and badly preserved cast of left valve, P.M.O. no. 37648, probably from Furuberget, Hamar, Cyclocrinus beds, 4b. Leg.?

Description: The form seems to have been round with an evenly curved anterior margin, and a relatively short, straight posterodorsal margin. Umbo very gibbous, prosogyrous, and projecting. The anterior slope is convex to flat, the posterior slope steeply falling off towards the dorsal margin, and flat or slightly concave. Parts of the shell are preserved showing traces of a radiating sculpture apparently crossed by concentric lines giving the surface a slightly reticulated appearance. The measurements might have been approximately: Heigth 32 mm, length 27 mm, semidiameter 6 mm.

Remarks: *A. orbicularis* Hall was described from the Lower Trenton limestone at Waterstown, Jefferson County. The form and the remaining parts of the sculpture indicate an affinity of the Norwegian specimen to *A. orbicularis*, but the specimen is too defective to allow a determination with certainty.

Genus *Ambonychinia* Isberg, 1934

Studien über Lamellibranchiaten des Leptaenakalkes in Dalarna, p. 29.

Type of genus: Ambonychinia undulata Isberg, 1934.

Ambonychinia aff. *amygdalina* (Hall, 1847) as of Ulrich, 1894.

Plate III, fig. 39.

Ambonychia amygdalina Hall: Palæntology of New York, vol. I, p. 165, pl. XXXVI, fig. 6a, b, c.

Material: Internal cast of one right valve, P.M.O. no. 7286, from western side of Røysetangen, Ringerike, calcareous mudstone, 4b. Leg. J. Kiær, 1913.

Description: Form oblique triangular, anterior margin rapidly sloping and convex, ventral margin apparently strongly curved, posterior margin convex and more or less parallel to the anterior margin, dorsal cardinal margin straight, approximately 16 mm long. Umbonal ridge broad, rapidly descending anteriorly where the shell is nearly vertical to the median axis, concavely sloping towards the posterior margin. No sculpture visible. Hinge and muscle scars not seen. Height (largest measured) 27 mm, length 21 mm, semidiameter at least 7 mm.

Remarks: This specimen closely resembles a shell figured by Ulrich (1897, pl. XXXV, figs. 8, 9), and named *A. amygdalina* Hall, and resembles to some extent *Ambonychia* cf. *intermedia* Isberg, 1934, of Reed (1953, pl. IV, fig. 6). It is, however, rather different from the original figure of Hall (1847) and from the specimens figured by Hind (1910) and Reed (1952) under the same name. All these specimens are larger than the Norwegian specimen, which therefore with doubt is suggested to have affinities to the original *amygdalina* of Hall. The species was described from the upper parts of the Trenton limestone, Adams, Jefferson County. Ulrich (1894) reports it from the Middle Galena of Minnesota, and Hind (1910) from the Llandeilo beds, Scotland.

Ambonychinia cf. *quadrata* (Hind, 1910)

Plate III, fig. 40.

Ambonychia quadratus Hind: Trans. Roy.Soc. Edinburgh, vol. XLVII, part XVIII, p. 490, pl. II, figs. 1—3.

Material: Internal cast of one right valve, P.M.O. no. 40312, from Vestbråten, Ringerike, calcareous mudstone, 4bγ, Leg. L. Størmer, 1955.

Description: The quadratic form of this species is very characteristic. Anterior margin convex and sloping, ventral margin slightly curved and subparallel to the dorsal margin, posterior margin slightly convex and parallel to the anterior margin. Anteroventral corner broadly rounded, posteroventral corner narrowly rounded, ventral and posterior margins forming an angle of about 90° with the posterior margin. Dorsal cardinal margin straight, forming an angle of slightly more than 90° with the posterior margin. Umbonal ridge strongly developed, convex, towards the anterior margin, concave towards the dorsal and posterior margins. Sculpture consists of irregularly and broadly spaced concentric growth-lines. Height 24.2 mm, length about 22.5 mm, cardinal margin about 13.5 mm.

Remarks: Ambonychia quadratus Hind was described from the Llandovery (Upper to Lower) and Llandeilo series (Balclatchie, Ardmillan) of Scotland. This species has therefore existed from the Lower Middle Ordovician to Middle Silurian.

There are slight differences between the outline of the Norwegian specimen and the figures given by Hind; also the growth-lines indicate that the form of younger specimens is more elongate. However, the affinities to *A. quadratus* Hind are unmistakeable.

Ambonychinia? species A.

Plate III, fig. 41.

Material: Internal cast of one right valve, P.M.O. no. 65049, from the Gagnum shale, Hadeland, 4bδ. Leg. J. A. Dons, 1944.

Description: The cardinal margin is broken off and the specimen therefore appears to be narrowly pointed with an acute umbonal angle, which, however, seems to have been about 90°. The ventral margin forms a semicircle with the posterior and anterior margins. The specimen is not much inflated. The beak seems to have been rather acute and slightly prosogyre. The sculpture consists of numerous fine, narrowly spaced, concentric lines, and two radiating folds are clearly visible on the posterodorsal corner. Heigth c. 17.5 mm, length c. 14 mm.

Remarks: Whether this specimen really belongs to the genus *Ambonychinia* can not be decided on the cast. It has some affinities to other genera of the family. In fact, the form resembles the figure of *A. amygdalina* Hall of Hind (1910, pl. I, fig. 28) but the fine concentric sculpture and the two radiating folds are not mentioned by Hind. *A. unisulcata* Isberg, 1934, shows the same radiating folds but is broader and has a more inflated umbo.

Genus *Clionychia* Ulrich, 1892

American Geologist, Vol. X, p. 97.

Type of genus: Ambonychia lamellosa Hall, 1861.

Remarks: This genus, which is characterized by the small, terminal beaks and relatively flat shell with an anterior angle of less than 90°, is represented by several samples. Most of them consist of pressed or deformed casts, which are impossible to describe or to refer to known species. These are therefore listed under *Ambonychiidae* spp.

Clionychia undata (Emmons, 1842)

Plate III, fig. 42.

Pterinea undata Emmons: Geological Report of New York, 1842, p. 395, fig. 1.

Material: One right valve, P.M.O. no. 58264, from S. of Røykenvik, Hadeland, 4bβ-γ. Leg. T. Strand, 1933.

Description: Form oblique quadratic, anterior margin slightly concave forming an angle of little less than 90° with the hingeline. Anteroventral corner broadly rounded continuing in the evenly rounded ventral margin and posteroventral corner; posterior margin convex and nearly parallel to the anterior margin, dorsal margin straight forming a blunt angle with the posterior margin. Umbo anterior, pointed somewhat protruding. Umbonal keel rather flat but steeply descending towards the concave anterior margin; posterior slope flat or slightly concave. Sculpture consists of 14—15 irregular concentric folds with broad interspaces. Traces of finer concentric lines are also visible, especially anteriorly. Maximal length from umbo to posteroventral curvature 44 mm, horizontal length 36.5 mm, height vertical to dorsal margin c. 35 mm, length of hingeline 26.5 mm.

Remarks: This specimen is so close to the American species that a reference to it seems to be safe. *C.undata* (Emmons) was described from the Upper Trenton limestone and later reported by Ulrich (1894) from the Middle Galena and by Hind (1910) from the Llandeilo beds, Scotland. Portlock (1943, p. 423, pl. XXXVI, fig. 1, 2, 3) described a Silurian fossil as a variety of *Inoceramus vetustus* Sowerby, 1829, and gave it the varietal name *priscus*. Hall (1847, p. 165—166) points to the resemblance of this variety to *C.undata* and considers it to be of Lower Silurian (=Ordovician) age. Reed (1952) has discussed and revised the material of Portlock's *I.vetustus* var. *priscus* and found that Portlock's three figures represent three different species of which one, *priscus* is referred to the genus *Ambonychinia* Isberg and the other two are placed in the genus *Clionychia* and given new names. One of these which Reed names *subovalis*, was figured by Portlock (Pl. XXXVI, fig. 2) and refigured by Reed (Pl. IV, fig. 7). Reed's figure, however, is very unclear, but apparently represents the same specimen figured by Portlock, This specimen resembles *C.undata* (Emmons) closely and the difference mentioned by Reed seem to fall within the range of specific variation.

The figures given by Hall (1847, pl. 36, fig. 7a, b) and Ulrich (1894, pl. XXXV, fig. 21, 22) are rather different, a fact which also is stated by Ulrich on p. 497. The original figure of Emmons (1842) was not accessible to us.

Clionychia species A.

Plate III, fig. 43.

Material: Internal cast and a mould of one right valve, P.M.O. no. 18881, 18882, from the new Drammensvei between Sandvika and Slependen in the neighbourhood of syenitic veins, Chasmops shale, 4b*a*. Leg. A. Heintz, 1932.

Description: Shell rather flat, with the strongest inflation or umbonal ridge along the anterior margin, which is sharply bent. Sculpture consists of fine concentric lines especially distinct along the anterior margin, further 3—4 growth lines, and traces of weak concentric undulations on the umbo. Hinge and muscle scars not observed. Height 26 mm, length 23 mm, semidiameter c. 3 mm.

Ambonychiidae spp.

There are several casts which probably should be referred to this family. Some of them may belong to the genus *Clionychia*, but most of them are so badly preserved that a reference to a genus with some certainty is impossible. They are therefore only listed here: From Sphaeronid shale (4bδ), Grymyr, Gjøvikodden, Hadeland, leg. J. Kiær, 1925; there are 6 samples P.M.O. nos. 5773, 5774, 5775, 5776, 5777, and 5788, perhaps containing 3 different species.

From Lower Chasmops limestone (4bβ), Juern below Frok, Ringerike, leg. J. Kiær, 1920, one sample P.M.O. no. 8259.

FAMILY PTERIIDAE MEEK,

Genus *Leptodesma* Hall, 1883

Palæontology of New York, vol. V, pt. 1.

Type of genus: Leptodesma potens Hall, 1883.

Leptodesma cf. *transversa* Hind, 1910

Plate IV, fig. 44.

Leptodesma transversa Hind: Trans. Roy. Soc. Edinburgh, vol. XLVII, part XVIII: p. 498, pl. I, figs. 17—19.

Material: Cast of one right valve, P.M.O. no. 38198, from Furuberget, Hamar, Cyclocrinus beds, 4b. Leg. J. Kiær, 1920.

Description: Shell small, ovate, beaks in anterior third. Dorsal margin straight, anterior wing broken, anterior margin broadly rounded to the convex ventral margin, which is more or less parallel to the dorsal margin. Posteroventral corner apparently broadly rounded with the posterior margin slightly concave forming an angle of 90° with the hinge-line and without a posterior spine, which, however, is clearly indicated in the sculpture of the older parts of the valve. Umbonal ridge distinct and has the ventral slope slightly convex and a concave dorsal slope. Greatest convexity in the middle of the umbonal ridge. Sculpture consists of fine, slightly irregular concentric lines. An impressed line parallel to the posterior hinge margin is rather distinct. Length 12.5 mm, height 8.3 mm.

Remarks: This specimen agrees so well with *L. transversa* Hind, that we think it probably could be identified with it without reservation. *L. transversa* was described from the Lower Llandovery of Mulloch Hill, Scotland. It has also affinities to *L.naviforme* Hall, 1883, from the lower beds of the Chemung group, Ithaca, New York.

FAMILY MODIOLOPSIDAE FISCHER, 1887

Two species are referred to the genus *Modiolopsis* Hall, but as no good specific character could be found on the casts, they are listed as species A and B. Though some of the indeterminable samples migh belong to this family, the scarcity of species and specimens of the family *Modiolopsidae* is obvious.

Genus *Modiolopsis* Hall, 1847

Palæontology of New York, vol. I, p. 157.

Type of genus: Cypricardites ovatus Conrad, 1841, cf. Ulrich in Foerste (1924).

Modiolopsis species A.

Plate IV, fig. 45.

Material: Internal cast of right valve, P.M.O. no. 56675, from S. of Røykenvik, Hadeland, lower part of Chasmops limestone, 4bβ-γ. Leg. O. Holtedahl, 1920.

Description: Shell elongate ovate, narrowing anteriorly, ventral and dorsal margins forming an angle of about 20°. Umbones large, prosogyre and projecting, placed near the anterior end. Anterior margin slightly concave with a rounded anteroventral corner. Ventral margin nearly straight, posterior margin broadly rounded forming a rounded corner with the nearly straight dorsal margin. The mesial depression is broad and gives a slight concave curvature to the ventral margin. The umbonal ridge is distinct, and the posterior slope relatively steep. Very faint traces of a concentric sculpture are visible. On the umbonal ridge and its dorsal slope there are indications of many faint radiating striae. Anterior muscle scar distinct and large, reaches inwards below the beak. Length 20 mm, height 12.5 mm, semidiameter about 4 mm.

Remarks: Though the cast is in a very good state of preservatiou we have been unable to refer the specimen to any of the known species. So far we can decide, it resembles *M.borealis* Foerste, 1924, in form, but lacks the radiating striae on the mesial depression.

Modiolopsis? species B.

Plate IV, fig. 46.

Material: Several internal casts, P.M.O. nos. 34307, 34309, from S. of Røykenvik, Hadeland, Cyclocrinus beds, 4b. Leg. O. Holtedahl, 1917.

Description: Shell small, elongate, subrhomboidal, a little higher posteriorly than anteriorly with subparallel dorsal and ventral margins. Umbones large, anterior; umbonal ridge angulated with a steeply descending dorsal slope and a mesial flat part, which also gives the umbones a flat top. Anterior margin curved, posterior margin obliquely truncate with a rounded ventral corner and angulated dorsally. Sculpture consists of irregular growth-lines. Length 7 mm, height c. 4 mm.

Remarks: These specimens are with doubt referred to the genus *Modiolopsis*. The rather sharp umbonal ridge and the form have some resemblance to *Modiolopsis vera* Foerste, 1924, but the dorsal margin is more straight and there is a posterodorsal angle (P.M.O. no. 34307); while another specimen (P.M.O. no. 34309) is of a slightly different form and should perhaps be referred to a different species. These specimens have also a strong resemblance to *Modiolopsis maia* Billings, 1865, described from Canadian Trenton, but they should probably be placed in another genus e.g. *Ectenocardimorpha* Isberg, 1934, *Endodesma* Ulrich, 1894, or *Orthodesma* Hall and Whitfield, 1875.

Modiolopsidae sp.

Material: Two strongly pressed and distorted internal casts of right valve, P.M.O. no. 7290, from the western side of Røysetangen, Ringerike 4b. Leg. J. Kiær, 1913.

FAMILY ALLODESMIDAE DALL, 1889

Genus *Allodesma* Ulrich, 1894

Geology of Minnesota, vol. III, part II, p. 617.

Type of genus: Modiolopsis subelliptica Ulrich, 1892.

Remarks: This genus established by Ulrich for the inclusion of a small elongate species with a distinct anterior muscle scar, bordered posteriorly by a strong curved ridge and a hinge with one or two posterior laterals, was apparently monotypical, except for an undetermined or undescribed *Allodesma?* species from the Trenton fauna of Baffin Land (Schuchert 1900). However, many specimens and moulds of a small thickshelled species from Gran, Hadeland, seem to be referable to this genus and to belong to an undescribed species.

Allodesma elegantula n.sp.

Plate IV, figs. 47–52.

Material: Many specimens and moulds, P.M.O. nos. 35335, 35336, 35337, 35344, 35345, 35346, 35347, 35348, 35350, from S. of Gran, Hadeland. Upper Middle Ordovician. Leg. O. Holtedahl, 1917.

Holotype: One left valve, P.M.O. no. 35345.
Type locality: Gran, Hadeland.
Type horizon: Upper Middle Ordovician.

Diagnosis: Shell small, elongate-ovate, slightly variable in outline, inequilateral, the umbones in the anterior third or fourth, more median in young specimens. Anterior margin evenly rounded with rounded corners, ventral margin convex, posteroventral corner narrowly rounded, more or less distinct. Posterior margin subtruncate to rounded, usually with a slightly convex ventral part evenly curved towards the dorsal margin, which is nearly straight. Beaks prosogyre, small, somewhat projecting, Umbonal ridge not conspicuous, sometimes with a slight sulcus in front, rounded. Dorsal slope steep and slightly concave in the proximal part, flattening towards the posterior end; median part of the valve slightly convex to flat, anterior slope convex. Greatest convexity in the middle of the shell. There is a small but distinct lunule but an escutcheon seems not to be developed.

The shell is extremely thick for its size. The sculpture consists of numerous narrowly spaced fine concentric lines, less distinct on the posterior slope, and crossed by fine thread-like radial lines on, and just before the umbonal ridge. Twentytwo radial lines could be counted on the holotype.

Anterior adductor scar large, round, placed in the upper half of the anterior end, bordered posteriorly by a strong, curved ridge which is broad dorsally, tapering off ventralwards. The anterior side of the scar is bordered by a thickening of the margin. Just above the posterodorsal corner of the adductor scar there is a small retractor scar visible in some of the moulds. The posterior adductor scar is smaller, more elongate and placed near the posterior end close to the dorsal margin. This scar is bordered anteriorly by a more or less developed ridge. The casts of the interior show a rather broad and deep impression of the ridge bordering the anterior adductor and a much weaker one, sometimes absent, of the ridge before the posterior adductor. Pallial line simple, distant from the margin. Hinge could not be seen as the shells invariably were recrystallized, one mould, however, had indications of a long, posterior lateral.

Length 8 mm, height 5 mm, semidiameter 2 mm (holotype). Maximal length 10 mm.

Remarks: This species is easily recognized even in fragments on the peculiar, delicate sculpture on the umbonal ridge. It is referred to the genus *Allodesma* on account of the adductor scars and outline.

A. elegantula occurs in great quantities in layers in dark limestone together with various small species of gastropods, *Modiolopsis* species B, *Cuneamya? minuta* n.sp., brachiopods and fragments of many fossils, and must be considered to be a dominating member of the fauna of this bed.

A. subellipticum (Ulrich) from the Galena shales resembles our species in outline but is more elongate and lacks the delicate radiate sculpture. Ulrich (1894) has described *Sphenolium striatum* from the Middle Galena, the only species showing radial lines like those of *A. elegantula*, but other characters are different from our species.

FAMILY GRAMMYSIIDAE FISCHER, 1887

Three specimens can be referred to this family. We have placed the specimens with close-set concentric lines and anteriorly placed umbones in genus *Cuneamya*, while one fragment with doubt is referred to genus *Grammysia*.

Genus *Cuneamya* Hall and Whitfield, 1875

Paleontology of Ohio, vol. II, p. 90.

Type of genus: C. miamiensis Hall and Whitfield, 1875.

Cuneamya multistriata n.sp.

Plate IV, figs. 53–54.

Material: One cast and one mould of a right valve, P.M.O. no. 7260, from the western side of Røysetangen, Ringerike, 4b. Leg. J. Kiær, 1913.

Holotype: Mould with latex cast of a right valve, P.M.O. no. 7260.
Type locality: Western side of Røysetangen, Ringerike.
Type horizon: 4b.

Diagnosis: Shell quadrangular, ovate, elongate, of medium size, inflated, inequilateral with umbones close to the anterior end. Anterior margin convex, rapidly sloping with a rounded anteroventral corner. Basal margin nearly straight with a faint, concave sinuation in the anterior part. Posterior margin broadly rounded with rounded corners. Dorsal margin apparently straight. Umbones large, inflated. Umbonal ridge broadly rounded with the greatest convexity on the upper part. There is a lower anterior ridge nearly vertical from the umbones. The anterior slope is convex and steep. Near the anterior margin there seems to be a rather broad, flattened sulcus. Between the two ridges there is a shallow sulcus broadening and flattening ventralwards. The posterior slope is concave, steep in the proximal part. Sculpture consists of numerous concentric lines with narrow interspaces. These lines are finer and closer to each other on the anterior slope, but widening backwards where there are 9–10 lines on 2 mm. There are also some coarser growth lines making the sculpture more irregular. Hinge and muscle scars not visible.

Length 18.5 mm, height (posteriorly) 12 mm, semidiameter c. 4 mm.

Remarks: The cast and the mould were both in the same sample. While the cast was more or less compressed and crushed, the mould gave a perfect and nearly complete latex cast, which therefore was made the holotype. The form of this species agrees fairly well with *C. truncatula* Ulrich, 1894, but the sculpture is quite different. The form of our species and the fine concentric sculpture seem to be reliable characters for separating it from other species of the genus.

Cuneamya? minuta n.sp.

Plate IV, fig. 55.

Material: One left valve, P.M.O. no. 35336, from S. of Gran, Hadeland, Upper Middle Ordovician. Leg. O. Holtedahl, 1916.

Holotype: A left valve, P.M.O. no. 35336.
Type locality: S. of Gran, Hadeland.
Type horizon: Upper Middle Ordovician.

Diagnosis: Shell small, quadrangular elongate with subparallel dorsal and ventral margins, much inflated, with umbones near the anterior end. Anterior margin sloping, concave with a narrowly rounded anteroventral corner, ventral margin nearly straight with a slight concave sinuation in the middle. Posteroventral corner broadly rounded, posterior margin curved ending in a distinct posterodorsal angle of a little more than 90°. Dorsal margin straight or slightly convex. Umbones very large and inflated, umbonal ridge broadly rounded, the posterior and anterior slopes are convex but there is a distinct mesial depression giving the umbo a flattened surface. Sculpture consists of many slightly irregular, narrow, raised concentric lines with broad interspaces.

Hinge, dorsal areas and muscle scars not observable.

Length 2.1 mm, height 0.6 mm, semidiameter c. 0.5 mm.

Remarks: This small specimen is difficult to refer to its proper place in the system, but on account of the form and mesial depression, we place it tentatively in the genus *Cuneamya* Hall and Whitfield. It might be a young specimen, but the form and especially the sculpture are so distinct that we feel it should be possible to recognize it in larger specimens too.

Genus *Grammysia* De Verneuil, 1847

Bull. Soc. Geol. France, (2). 4. 1847, p. 696.

Type of genus: Grammysia hamiltonensis De Verneuil, 1847.

Grammysia? species A.

Plate IV, fig. 56.

Material: Part of a left valve, P.M.O. no. 7289, from the western side of Røysetangen, Ringerike, 4b. Leg. J. Kiær, 1913.

Description: The sculpture consists of irregular broad concentric folds with an anterior sulcus and a radial interruption of the concentric sculpture in front of the umbonal ridge. The length may have been a little more than 30 mm.

Remarks: If our reference to the genus *Grammysia* is correct, we find that the specimen has some resemblance to *Grammysia bisulcata* (Conrad, 1838).

Genus *Saffordia* Ulrich, 1894

Report Geological Survey of Minnesota. p. 625.

Type of genus: Saffordia ventralis Ulrich, 1894.

Saffordia? species A.

Plate IV, fig. 57.

Material: One right valve, P.M.O. no. 35331, from S. of Gran, Hadeland, Upper Middle Ordovician. Leg. O. Holtedahl, 1916.

Description: Shell short quadrangular with anterior umbones, inflated. Anterior margin convex, sloping, anteroventral corner narrowly rounded, ventral margin nearly straight, posterior margin broadly rounded continuing with an indefinite angle into the convex dorsal margin. Umbones large, umbonal ridge distinct, rounded, with a rather steep convex dorsal slope apparently with a sulcus. Median part of the valve flat, an anterior ridge indistinct, anterior slope convex. Sculpture consisting of irregular concentric lines with some stronger growth-lines. Hinge and muscle scars unknown. Lunule and escutcheon not observed. Length 6.5 mm, height 4.5 mm.

Remarks: This specimen is with doubt referred to the genus *Saffordia.* The form is very close to the figure given by Ulrich of *S. ventralis* and *S. modesta* (Ulrich, 1892), but can not be referred to any of them.

List of undetermined and indeterminable pelecypods.

P.M.O. no. 4262. W. of the road, Gullerud, Norderhov, Ampyx limestone, 4aβ, Leg. O. Holtedahl. A badly preserved internal cast may probably belong to family *Modiolopsidae.* Length 17.5 mm.

P.M.O. no. 40320. Slependen, Asker, 4bα. One cast about 25 mm long, ovate with concentric sculpture.

P.M.O. nos. 40325—40327. Roof of tunnel, W. of Billingstad, Asker, 4b*α*. Leg. N. Spjeldnæs, 1958. One deformed and pressed cast of a right valve, length 28 mm, height 17 mm, narrow umbones and expanded anterior margin, may belong to family *Modiolopsidae*. Further two internal casts of right valves.

P.M.O. nos. 7311, 7313. Western side of Røysetangen, Ringerike, 4b. Leg. J. Kiær, 1913. Two casts probably belonging to family *Ctenodontidae*.

P.M.O. nos. 7253, 7257, 7312. Western side of Røysetangen, Ringerike, 4b. Leg. J. Kiær, 1913. One cast length 9 mm and two casts about 20 mm may be *Cyrtodontula* species.

P.M.O. no. 5847. Ostøya, Bærum, 4b*β*. Leg. Th. Vogt. Internal cast of a left valve, small with rounded posterior margin and pointed, incurved umbones.

P.M.O. nos. 40321—40323. Hvalstad section, Asker, lower part, 4b*γ*. Leg. N. Spjeldnæs, 1957. Two casts and one mould of a small species with nearly anterior umbones and subtruncate posterior margin. May be distorted specimens of *Ctenodonta* species.

P.M.O. no. 7805. Above Vestbråten, Ringerike, 4b*γ*. Leg. J. Kiær, 1920. Part of cast, may be a *Cyrtodontula*.

P.M.O. no. 34315. S. of Røykenvik, Hadeland, Cyclocrinus beds, 4b. Leg. O. Holtedahl. Internal cast of a small specimen, ovate, rather inflated with broad, flat umbones. Length 5 mm.

P.M.O. 8129—8135. Frog, Ringerike, 4b*δ*. Leg. Mrs. Quale. Badly preserved and distorted casts of which some resemble *Ctenodonta* while others, probably should be referred to the families *Cyrtodontidae* and *Modiolopsidae*.

P.M.O. no. 34574. Gjøvik, Cyclocrinus beds, 3—4 m above the limestone, 4b. Leg. O. Holtedahl. Part of a mould of a relatively large, elongate specimen furnished with regular concentric sculpture.

P.M.O. 35330 (Pl. IV, fig. 58) S. of Gran, Hadeland, 4a*α*, lowermost part. Leg. O. Holtedahl, 1916. Internal cast of a left valve, ovate, with umbones before the middle, concentric sculpture. Length about 7 mm.

Faunal assemblages and stratigraphical range.

As mentioned in the introduction, no systematical sampling of Middle Ordovician pelecypods has been undertaken. The material must therefore give only a fragmentary picture of what may be expected to occur in these horizons. Only 4 species, two indeterminable, are referred to horizons 4aα-β. The majority of the species have been collected in horizons 4bα-γ, including the Cyclocrinus beds, 3 species are referred to 4bδ and one to 4c which equals Lower Upper Ordovician.

The accompanying table, p. 118—119, shows the distribution of the species in the various horizons and districts. The districts are those used by Størmer (1953). From the table is seen that the majority of the species is found in the Ringerike and the Hadeland districts. The richest locality is the western side of Røysetangen, Ringerike, listed as 4b, but probably mainly restricted to 4bα, where the following 11 species have been collected: *Ctenodonta spjeldnaesi* n.sp., *Cyrtodontula dubia* n.sp., *Cyrtodontula* species A, *Cyrtodontula* species B, *Cyrtodontula* aff. *complanata*, *Vanuxemia* species A, *Vanuxemia* species B, *Ambonychinia* aff. *amygdalina*, *Cuneamya multistriata* n.sp., *Grammysia?* species A, and *Modiolopsidae* sp. Next in importance is Røykenvik, Hadeland, 4bβ-γ, with the following 4 species: *Ctenodonta* species D, *Ctenodonta* species E, *Clionychia undata* and *Modiolopsis* species A. The locality Vestbråten, Ringerike, 4bγ, yielded material relatively rich in specimens, but restricted to 3 species only, viz.: *Ctenodonta spjeldnaesi* n.sp., *Cyrtodontula* aff. *complanata*, and *Ambonychinia* cf. *quadrata*. A curious fauna of small species quite unlike the fauna of the other localities, was found S. of Gran, Hadeland. They are listed as Upper Middle Ordovician as the proper placement of this horizon is not yet settled. 5 species have been listed from this locality viz.: *Ctenodonta* species C, *Ctenodonta* species H, *Allodesma elegantula* n.sp., *Cuneamya? minuta* n.sp. and *Saffordia?* species A. *Allodesma elegantula* n.sp. was present in numerous specimens.

Growth.

Many specimens of several species show more or less pronounced irregularities in the concentric sculpture. In some species these irregularities form definite steps very like those found in recent species, where they are caused by a pause in the growth of the valves. These growth-stops can usually be correlated to the seasons of the year, but may also have other causes such as a sudden change in the ecological conditions, or may perhaps even be connected with the spawning period. The irregularities seen on the fossils may undoubtedly be due to similar causes, and we are most inclined to think that they represent the yearly cycles. If this is so, there must either have been a pronounced difference of physical factors throughout the year or in the supply of food.

Usually the growth-stops are visible in the younger part of the valve only and the earliest growth-stops have been too vague to be detected on the fossils. We have, however, counted what could be seen on the specimens and give here a list of the result.

Species:	Growth-stops:
Ctenodonta spjeldnaesi n.sp.	6—7, 4 on the younger part
Cyrtodontula dubia n.sp.	4, very distinct
Cyrtodontula species A.	2
Cyrtodontula species B.	3—4
Cyrtodontula aff. *complanata* (Foerste)	3—10
Cyrtodontula aff. *subtruncata* (Hall)	3
Cyrtodontula species E.	4
Vanuxemia species B.	7, distinct
Ambonychinia cf. *quadrata* (Hind)	4
Clionychia species A.	5
Leptodesma cf. *transversa* Hind	3
Modiolopsis species A.	6
Cuneamya multistriata n.sp.	6

This list shows that if the growth-stops represent years, the minimum age of the species is 3 to 10 years. The growth-stops in *Vanuxemia* species B (Pl. III fig. 37) are very distinct and can be counted from the first stop. This specimen apparently was 7 years old when it died. We have also measured the length along a line from umbo to the postero-ventral angle of the various growth-stops on the specimens. The distance between these or the yearly increase of the shell along this line are: I — 4.5 mm, II — 5.7 mm, III — 2.6 mm, IV — 2.9 mm, V — 3.4 mm, VI — 2.9 mm, and VII — 1.0 mm. The growth has been rapid the two first years, nearly constant the succeeding 4 years, and

Pelecypod genera and species	HORIZONS				
	4 aα_3	4 aβ	4 bα	4 bβ	4 bγ
Ctenodonta nuda n.sp.					
Ctenodonta ? species A.	x				
Ctenodonta spjeldnaesi n.sp.					x
Ctenodonta norvegica n.sp.				x	
Ctenodonta species B.				x	
Ctenodonta species C.					
Ctenodonta species D.					
Ctenodonta species E.				x	
Ctenodonta ? species F.					
Ctenodonta ? species G.					
Ctenodonta ? species H.					
Ctenodonta species I.					x
Ctenodonta species K.			x		
Cyrtodontula dubia n.sp.					
Cyrtodontula species A.					
Cyrtodontula species B.			x		
Cyrtodontula aff. complanata			x		x
Cyrtodontula species C.				x	
Cyrtodontula aff. subtruncata		x			
Cyrtodontula species D.			x		
Cyrtodontula cf. compressa					
Cyrtodontula species E.				x	
Vanuxemia ? species A.					
Vanuxemia species B.					
Ambonychia aff. orbicularis					
Ambonychinia aff. amygdalina					
Ambonychinia cf. quadrata					x
Ambonychinia ? species A.					
Clionychia undata					
Clionychia species A.			x		
Ambonychiidae spp.				x	
Leptodesma cf. transversa					
Modiolopsis species A.					
Modiolopsis ? species B.					
Modiolopsidae sp.					
Allodesma elegantula n.sp.					
Cuneamya multistriata n.sp.					
Cuneamya ? minuta n.sp.					
Grammysia ? species A.					
Saffordia ? species A.					
	1	1	5	6	4

						DISTRICTS			
4 bβ-γ	4 bδ	4 b	Cyclocrinus-beds	Upper Middle Ordovician	4 c	Oslo—Asker	Ringerike	Hadeland	Nes—Hamar
			x						x
								x	
		x					x		
						x			
						x			
				x				x	
x								x	
								x	
			x						x
	x						x		
				x				x	
						x			
						x			
		x					x		
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			x						x
x								x	
			x					x	
		x					x		
				x				x	
		x					x		
				x				x	
		x					x		
				x				x	
3	3	11	5	5	1	5	18	13	5

slow the 7th year as the specimen then had reached near the maximum length. These figures are in good agreement with growth of recent pelecypods.

A fact which makes the counting of year-rings very difficult is the crowding of them along the often thickened margins of old specimens. Several specimens e.g. of *Ctenodonta spjeldnaesi* n.sp., *Ctenodonta* species E, *Cyrtodontula dubia* n.sp., *Cyrtodontula* aff. *complanata* Foerste and *Clionychia* species A, showed just this gerontic character, indicating that some years must be added to what the discernible growth-stops suggest in order to reach the real age of the specimens. The presence of so many gerontic specimens indicates that the pelecypods lived under suitable conditions. They seem to have had few enemies and no specimens were bored by carnivorous gastropods.

Faunal affinities.

The scattered samples of generally badly preserved specimens are not sufficient for a real comparison with Middle Ordovician faunas from other regions. The species from 4bβ-γ have decided affinites to Eastern North America (Trenton etc.) and to Girvan, Scotland (Llandeilo). The fauna of the beds S. of Gran, Hadeland, with numerous specimens of *Allodesma elegantula* n.sp. also points towards North American Ordovician, but perhaps also to faunas of the Arctic, e.g. Baffin Land.

There seem to be no connections with the Ordovician of southern and eastern Europe, but our knowledge of e.g. the Esthonian Ordovician is too fragmentary to allow a definite conclusion. There might perhaps be some similarities to the Ordovician of East Asia, but until all vaguely circumscribed species or groups of species, have been carefully compared, and the Norwegian fossil pelecypods studied on a much larger scale, it is best to avoid all conclusions.

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Manuscript received June 25, 1959.
Printed June 1960.

PLATE I.

Fig. 1. *Ctenodonta nuda* n.sp. Holotype. Furuberget, Hamar 4b. Internal cast of right valve, P.M.O. no. 38152. Length 15 mm, x 1.9.

Fig. 2. *Ctenodonta ?* species A. Gran, Hadeland, Ogygiocaris shale, 4a*α*. Internal cast of right valve, P.M.O. no. 33245. Length 5 mm, x 4.4.

Fig. 3. *Ctenodonta spjeldnaesi* n.sp. Holotype. Vestbråten, Ringerike, Upper Chasmops shale, 4bγ. Left valve, P.M.O. no. 40308. Height 12.6 mm, x 1.7.

Fig. 4. *Ctenodonta spjeldnaesi* n.sp. Paratype. Vestbråten, Ringerike, Upper Chasmops shale, 4bγ. Left valve with parts of hinge, P.M.O. no. 40315. Length 9 mm, x 2.8.

Fig. 5. *Ctenodonta spjeldnaesi* n.sp. Paratype. Vestbråten, Ringerike, Upper Chasmops shale, 4bγ. Left valve, oblique dorsal view of hinge, P.M.O. no. 40315. Length 9 mm, x 2.8.

Fig. 6. *Ctenodonta spjeldnaesi* n.sp. Paratype. Vestbråten, Ringerike, Upper Chasmops shale, 4bγ. Internal cast of right valve, P.M.O. no. 40307, Length 12 mm, x 2.4.

Fig. 7. *Ctenodonta norvegica* n.sp. Holotype. Langåra, Asker, 4bβ, Left valve, P.M.O. no. 6572. Height 9.5 mm, x. 2.9

Fig. 8. *Ctenodonta norvegica* n.sp. ? Langåra, Asker, 4bβ. Left valve, of narrow specimen, P.M.O. no. 6573. Height 5 mm, x 3.2.

Fig. 9. *Ctenodonta* species B. Ostøya, Bærum, 4bβ. P.M.O. no. 5846. Height 4 mm, x 5.0.

Fig. 10. *Ctenodonta* species C. S. of Gran, Hadeland, Upper Middle Ordovician. Right valve, P.M.O. no. 35332. Height 7 mm, x 3.1.

Fig. 11. *Ctenodonta* species D. S. of Røykenvik, Hadeland, 4bβ-γ. P.M.O. no. 58265. Height c. 5.5 mm, x 4.1.

Fig. 12. *Ctenodonta* species E. S. of Røykenvik, Hadeland, 4bβ-γ. Left valve, P.M.O. no. 33835. Height 11 mm, x 2.5.

Fig. 13. *Ctenodonta ?* species F. Furuberget, Hamar, Cyclocrinus beds 4b. Internal cast of left valve, P.M.O. no. 37861. Height c. 5 mm, x 4.4.

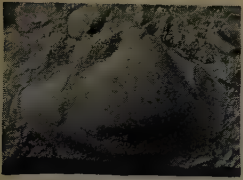
Fig. 14. *Ctenodonta ?* species G. Ringsås, Ringerike, Upper Chasmops limestone, 4bδ. Internal cast of right valve, P.M.O. no. 8222. Length 9.5 mm, x 3.0.

Fig. 15. *Ctenodonta ?* species H. S. of Gran, Hadeland, Upper Middle Ordovician. Internal cast, P.M.O. no. 35333. Length 11.5 mm, x 2.6.

Fig. 16. *Ctenodonta* species I. Hvalstad, Asker, 4bγ, lower part. Internal cast of left(?) valve showing the posterior taxodont teeth, P.M.O. no. 69561. Length 6 mm, x 4.2.

Fig. 17. *Ctenodonta* species K. Bilingstad, Asker, 4bα, Internal cast of right valve, cat. no. 69563. Length 9.5 mm, x 3.0.

PLATE I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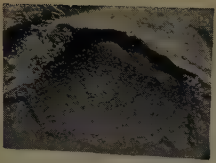
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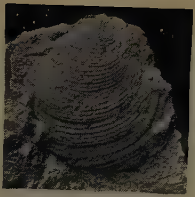
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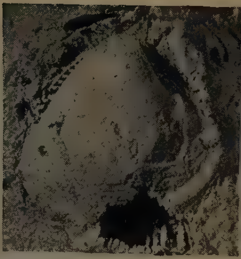
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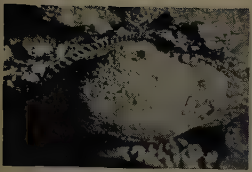
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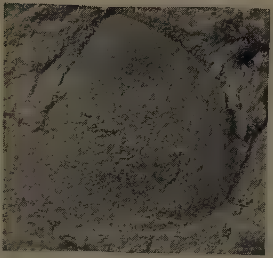
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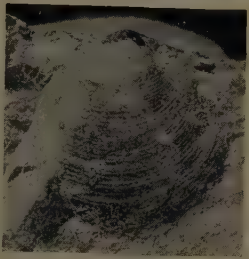
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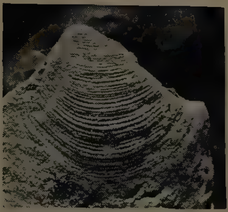
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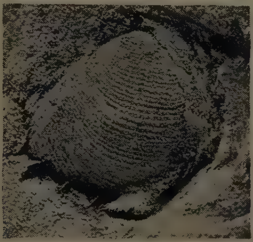
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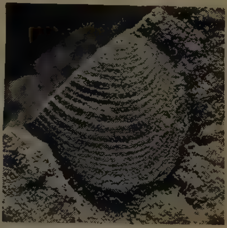
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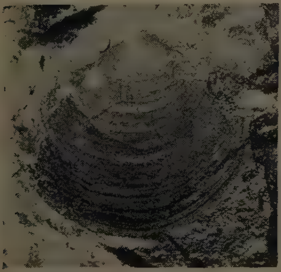
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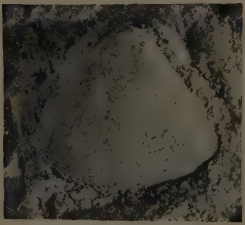
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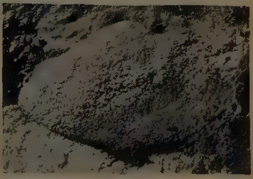
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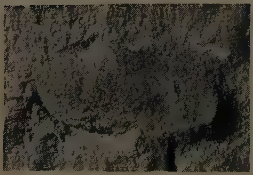
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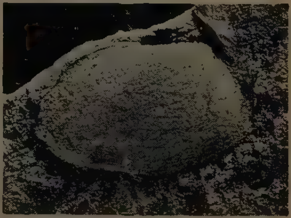
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PLATE II

Fig. 18. *Cyrtodontula dubia* n.sp. Holotype. Røysetangen, Ringerike, 4b. Internal cast of left valve, P.M.O. no. 7254. Height 33 mm, x 1.

Fig. 19. *Cyrtodontula dubia* n.sp. Paratype. Røysetangen, Ringerike, 4b. Internal cast of left valve, P.M.O. no. 7297, height 34 mm, x 1.1.

Fig. 20. *Cyrtodontula dubia* n.sp. Paratype. Røysetangen, Ringerike, 4b. Internal cast of left valve showing the incurved umbones, P.M.O. no. 7300. Height 34 mm, x 1.1.

Fig. 21. *Cyrtodontula* species A. Røysetangen, Ringerike, Chasmops shale, 4b. Cast of left valve, P.M.O. no. 7287. Height of broken specimen 48 mm, x 1.0,

Fig. 22. *Cyrtodontula* species B. Bratterud, Ringerike, 4b*a*. Internal cast of left valve, P.M.O. no. 20614. Height of broken specimen 41 mm, x 1.25.

Fig. 23. *Cyrtodontula* aff. *complanata* (Foerste, 1914). Røysetangen, Ringerike, 4b. Left valve, P.M.O. no. 7288. Height 40 mm, x 1.15.

Fig. 24. *Cyrtodontula* aff. *complanata* (Foerste, 1914). Above Vestbråten, Ringerike, 4b*y*. Right valve, P.M.O. no. 7810. Height 22 mm, x 1.3.

Fig. 25. *Cyrtodontula* aff. *complanata* (Foerste, 1914). Røysetangen, Ringerike, 4b. Right valve, P.M.O. no. 7251. Height 17 mm, x 1.4.

Fig. 26. *Cyrtodontula* aff. *complanata* (Foerste, 1914), Bratterud, Ringerike, 4b*a*. Left valve, deformed?, P.M.O. no. 20592, Height 20 mm, x 1.25.

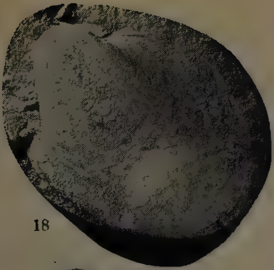
Fig. 27. *Cyrtodontula* species C. Furuberget, Hamar, Mastopora zone, 4bβ. Internal cast seen from the right side, P.M.O. no. 37528. Height 12.5 mm, x 2.4.

Fig. 28. *Cyrtodontula* species C. Furuberget, Hamar, Mastopora zone, 4bβ. Internal cast seen from the posterodorsal side, P.M.O. no. 37528. Height 12.5 mm, x 2.4.

Fig. 29. *Cyrtodontula* aff. *subtruncata* (Hall, 1847). Gullerud, Ringerike, 4aβ. Internal cast, from the right side, P.M.O. no. I—762. Height 36 mm, x 1.15.

Fig. 30. *Cyrtodontula* aff. *subtruncata* (Hall, 1847). Gullerud, Ringerike, 4aβ. Internal cast, posterodorsal view, P.M.O. no. I—762, Height 36 mm, x 1.25.

PLATE II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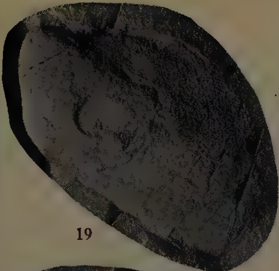
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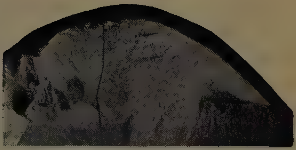
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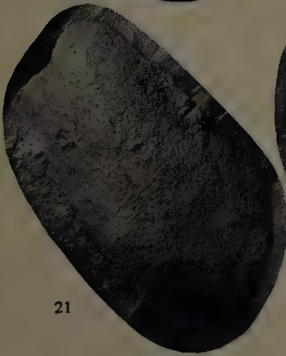
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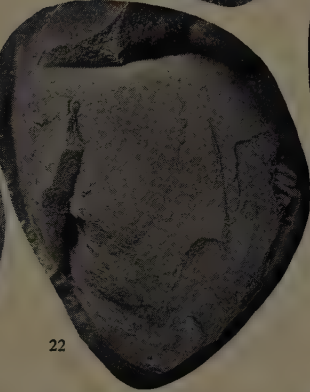
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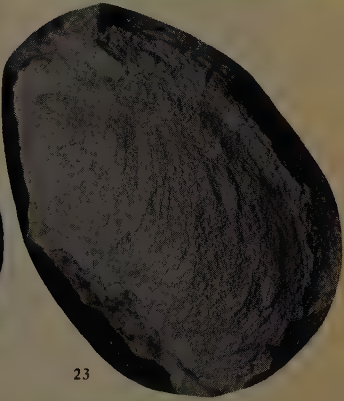
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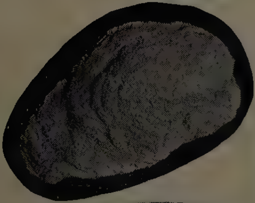
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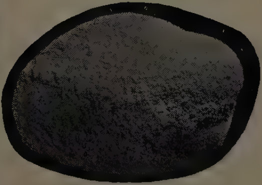
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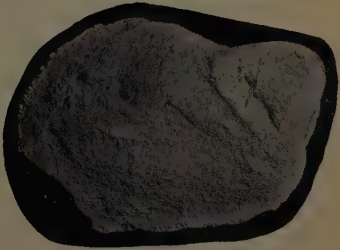
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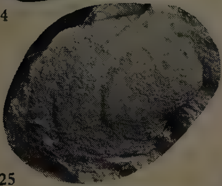
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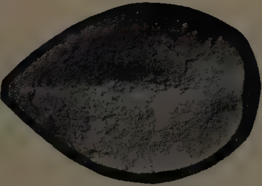
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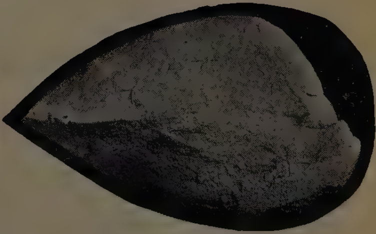
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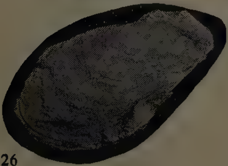
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PLATE III

Fig. 31. *Cyrtodontula* species D. Bratterud, Ringerike, 4bα. Internal cast, lateral view of right side with the anterior adductor scar, P.M.O. no. 20593. Height (largest measurement) 25 mm, x 1.4.

Fig. 32. *Cyrtodontula* species D. Bratterud, Ringerike, 4bα. Internal cast, postero-dorsal view, P.M.O. no. 20593. Height (largest measurement) 25 mm, x 1.4.

Fig. 33. *Cyrtodontula* cf. *compressa* (Ulrich, 1890). Frognøya, Tretaspis limestone, upper part, 4c. Internal cast of left valve, P.M.O. no. 30978. Height 18 mm, x 1.6.

Fig. 34. *Cyrtodontula* species E. Juern, Ringerike, Lower Chasmops limestone, 4bβ. Internal cast of left valve, P.M.O. no. 8267. Height 17.5 mm, x 1.5.

Fig. 35. *Cyrtodontidae?* species. Røysetangen, Ringerike, Chasmops shale, 4b. Internal cast from the left side, P.M.O. no. 7252. Height (largest measurement) 20.5 mm, x 1.6.

Fig. 36. *Vanuxemia?* species A. Røysetangen, Ringerike, 4b. Internal cast of right(?) valve, P.M.O. no. 7302. Height (largest measurement) 25 mm, x 1.6.

Fig. 37. *Vanuxemia* species B. Røysetangen, Ringerike, 4b. Latex cast of left valve P.M.O. no. 40305. Height (largest measurement) 22 mm, x 1.4.

Fig. 38. *Ambonychia* aff. *orbicularis* Hall, 1847. Probably Furuberget, Hamar. Cyclocrinus beds 4b. Internal cast of a broken left valve, P.M.O. no. 37648. Calculated height 32 mm, length of cardinal margin from umbo 12 mm, x 1.6.

Fig. 39. *Ambonychinia* aff. *amygdalina* (Hall, 1847) as of Ulrich 1894. Røysetangen, Ringerike, calcareous mudstone, 4b. Internal cast of right valve, P.M.O. no. 7286. Height (largest measurement) 27 mm, x 1.3.

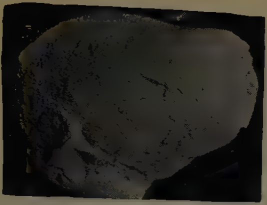
Fig. 40. *Ambonychinia* cf. *quadrata* (Hind, 1910). Vestbråten, Ringerike, calcareous mudstone, 4bγ. Internal cast of right valve, P.M.O. no. 40312. Height (largest measurement) 24.2 mm, x 1.6.

Fig. 41. *Ambonychinia?* species A. Gagnum shale, Hadeland, 4bδ. Internal cast of right valve, P.M.O. no. 65049. Height (largest measurement) 17.5 mm, x 1.6.

Fig. 42. *Clionychia undata* (Emmons, 1842). S. of Røykenvik, Hadeland, 4bβ-γ. Right valve, P.M.O. no. 58264. Largest measurement 44 mm, length of hinge line 26.5 mm, x 1.1.

Fig. 43. *Clionychia* species A. Between Sandvika og Slependen, Asker, shale, 4bα. Internal cast of right valve, P.M.O. no. 18882. Height (largest measurement) 26 mm, x 1.5.

PLATE III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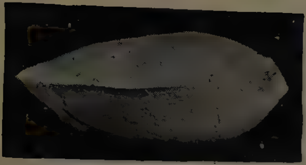
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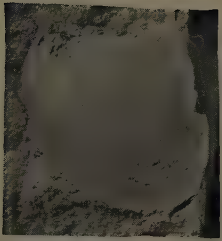
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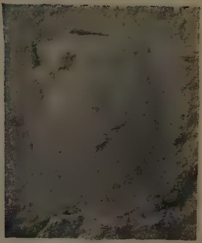
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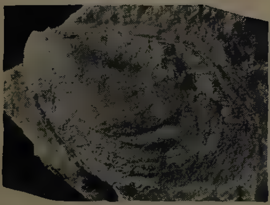
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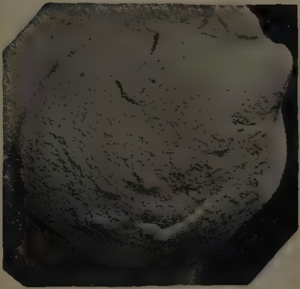
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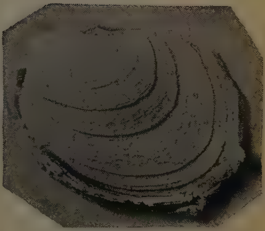
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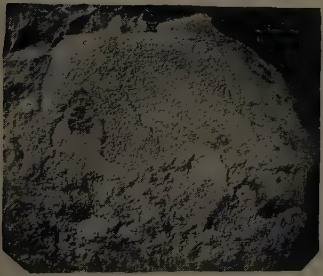
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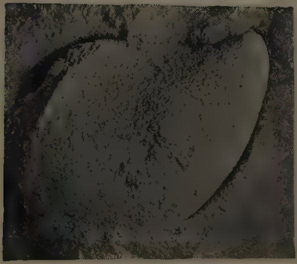
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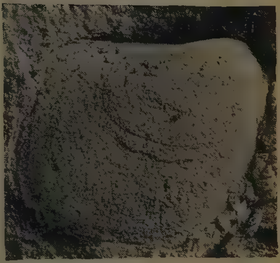
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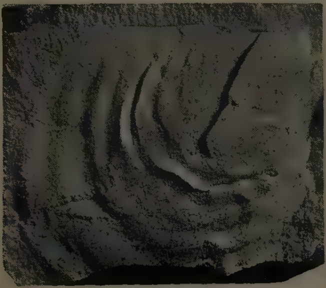
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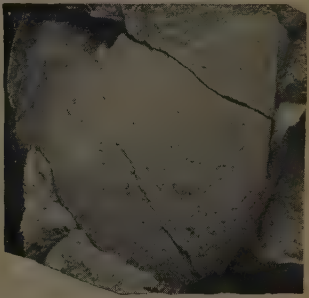
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PLATE IV

Fig. 44. *Leptodesma* cf. *transversa* Hind, 1910. Furuberget, Hamar, Cyclocrinus beds, 4b. Right valve, P.M.O. no. 38198. Length 12.5 mm, x 1.6.

Fig. 45. *Modiolopsis* species A. S. of Røykenvik, Hadeland, Chasmops limestone, lower part, 4bβ-γ. Internal cast of right valve, P.M.O. no. 56675. Length 20 mm, x 1.6.

Fig. 46. *Modiolopsis ?* species B. S. of Røykenvik, Hadeland, Cyclocrinus beds, 4b. Internal cast of right valve, P.M.O. no. 34307. Length 7 mm, x 3.0.

Fig. 47. *Allodesma elegantula* n.sp. Holotype. S. of Gran, Hadeland, Upper Middle Ordovician. Lateral view of left valve, P.M.O. no. 35345. Length 8 mm x 4.5.

Fig. 48. *Allodesma elegantula* n.sp. Holotype. S. of Gran, Hadeland, Upper Middle Ordovician. Dorsal view of left valve, P.M.O. no. 35345. Length 8 mm, x 4.5.

Fig. 49. *Allodesma elegantula* n.sp. Paratype. S. of Gran, Hadeland, Upper Middle Ordovician. Internal cast of left valve of a high specimen showing the impression of the ridge behind the anterior adductor, P.M.O. no. 35336. Length 9.5 mm, x 4.4.

Fig. 50. *Allodesma elegantula* n.sp. Holotype. S. of Gran, Hadeland, Upper Middle Ordovician. Highly magnified sculpture on the umbonal ridge, P.M.O. no. 35345.

Fig. 51. *Allodesma elegantula* n.sp. Paratype. S. of Gran, Hadeland, Upper Middle Ordovician. Mould of right valve showing the ridge behind the anterior adductor, P.M.O. no. 35336. Length 6 mm, x 5.5.

Fig. 52. *Allodesma elegantula* n.sp. Paratype. S. of Gran, Hadeland, Upper Middle Ordovician. The same mould as in fig. 31, with the light arranged in another way. The posterior adductor scar with ridge is seen near the posterodorsal corner, P.M.O. no. 35336. Length 6 mm, x 5.5.

Fig. 53. *Cuneamya multistriata* n.sp. Holotype. Røysetangen, Ringerike, 4b. Latex mould of right valve, P.M.O. no. 7260. Length 18.5 mm, x 1.6.

Fig. 54. *Cuneamya multistriata* n.sp. Paratype. Røysetangen, Ringerike, 4b. Right valve of a somewhat distorted specimen, P.M.O. no. 7260. Length 18 mm, x 1.6.

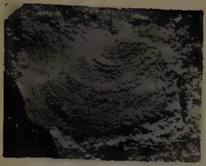
Fig. 55. *Cuneamya ? minuta* n.sp. Holotype. S. of Gran, Hadeland, Upper Middle Ordovician. Left valve, P.M.O. no. 35336. Length 2.1 mm, x 18.5.

Fig. 56. *Grammysia ?* species A. Røysetangen, Ringerike, 4b. Part of left valve, P.M.O. no. 7289. Original length probably 30 mm, largest measurement on piece 21.5 mm, x 1.5.

Fig. 57. *Saffordia ?* species A. S. of Gran, Hadeland, Upper Middle Ordovician. Right valve, P.M.O. no. 35331. Length 6,5 mm, x 3.0.

Fig. 58. Undetermined pelecypod. S. of Gran railway station, Hadeland, 4aα. Left valve, P.M.O. no. 35330. Length 7 mm, x 3.0.

PLATE IV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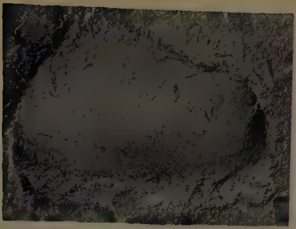
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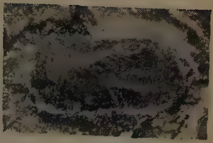
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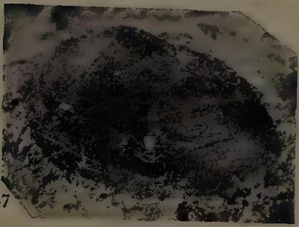
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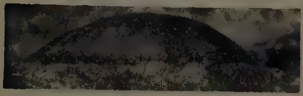
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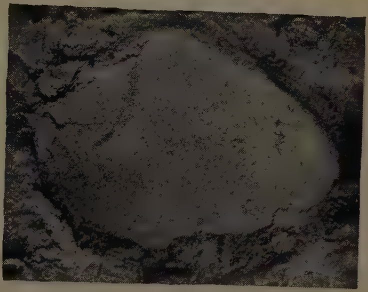
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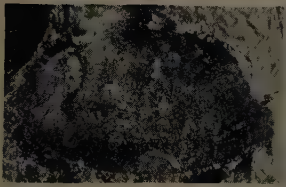
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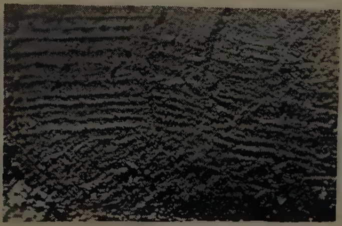
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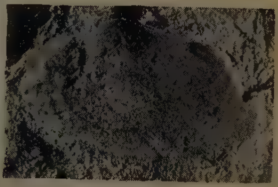
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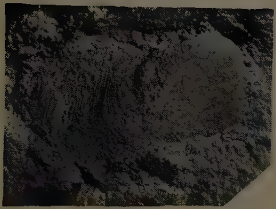
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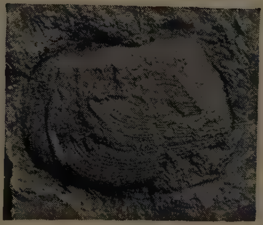
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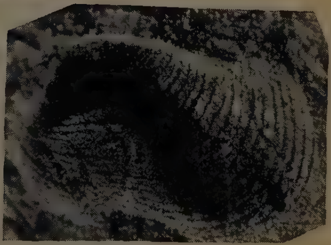
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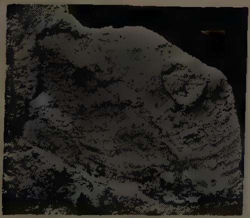
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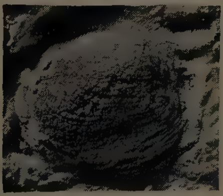
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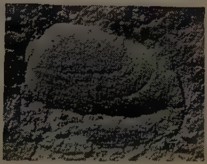
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THE MIDDLE ORDOVICIAN OF THE OSLO REGION, NORWAY

12. Notostraca and Conchostraca

By

HELEN SOOT-RYEN

Abstract. This paper deals with the first records of crustaceans of the orders *Notostraca* and *Conchostraca* from the Middle Ordovician of Norway. Two new species of notostracans are described, *viz. Technophorus stoermeri* and *Ischyrinia norvegica*, and furthermore *Eoasmussia heintzi* n.gen. et sp. of the order *Conchostraca*.

Preface

During the study of the material of pelecypods from the Middle Ordovician of the Oslo Region, some samples containing remains of small pelecypod-like crustaceans were found. As species of these groups never have been recorded from the Ordovician in the Scandinavian countries, and otherwise are scarce in Europe, I take the opportunity to describe two species of *Notostraca* and one species of *Conchostraca* which probably all are new to science.

I wish to express my heartiest thanks to Prof. L. Størmer who gave me the opportunity to work out this interesting material and allowed me to use his library. Prof. N. Novojilov, Moscow, has kindly studied two samples and has given his opinion on them. Dr. G. Henningsmoen and Dr. N. Spjeldnæs have helped me in many ways during the work and I am very indebted to both of them. Further I wish to extend my thanks to Miss Bergljot Mauritz and Mr. G. Brynhildsrud for making the photographs and to Prof. J. A. S. Adams who has corrected the manuscript.

Notostraca

The two species of *Notostraca* seem to belong to the genera *Technophorus* Miller, 1889 and *Ischyrinia* Billings, 1866. These genera are included in the family *Ribeiriidae* erected by Kobayashi (1933), who refers the family to the Notostracan order. The systematical position of this family is questionable and the species have been placed in several systematical units by various authors.

Sharpe (1853) erected the genus *Ribeiria* with *R. pholadiformis* Sharpe as the type of the genus. He noted that there was only one shell and therefore referred the genus to the Gastropoda. Salter (1884) was the first who assigned *Ribeiria* to the Crustacea. In 1865 and 1866, Billings erected 3 genera, *viz. Euchasma, Eopteria* and *Ischyrinia*, which all were referred to the Pelecypoda, and the same was the case with genus *Technophorus* Miller, 1889. During the years these genera were placed at random among gastropods, pelecypods, phyllopods and in the order *Archeostraca*. Schubert and Waagen (1903) discussed the systematical position of *Ribeiria* and placed it in the phyllopod family *Apodidae* together with a new genus, *Ribeirella* with *Ribeiria sharpei* Barrande, 1881 as type. Walcott (1924) erected a new genus *Ozomia*, which, however, now is considered to be a synonym of *Ribeiria*. The genera *Ribeiria, Ribeirella, Euchasma, Eopteria, Ischyrinia*, and *Technophorus* were placed in the order *Notostraca* Sars by Bassler (1913).

The most important study of these anomalous crustaceans is that of Kobayahsi (1933), who summarizes all earlier works on the group and establishes a systematical arrangement of the genera. His family *Ribeiriidae* comprises the two subfamilies *Ribeiriinae* and *Ischyriniinae* with, in all, 13 genera of which he has described 7 from Manchuria as new. He follows Bassler in referring this group provisionally to the *Notostraca*, though he finds it possible that the *Ribeiriidae* should be separated from the *Notostraca* and placed in an order of its own. Later he places the genus *Technophorus* in the family *Eopteriidae* Miller (Kobayashi, 1937).

According to the view of Kobayashi, the *Ribeiriidae* appeared first in Eastern Asia in Cambrian times (*Ribeiriinae*) and migrated eastwards, eventually reached Europe and finally disappeared in the Atlantic region during the Cincinnatian period. Few species are hitherto known from Europe, *viz.* two species of *Ribeiria* from the Lower Ordovician of Portugal and Llandeilo of England, and two species from the Lower and Middle Ordovician of Bohemia; one species of *Ribeirella* from the Upper(?) Ordovician of Bohemia, and one species of *Ischyrinia* from the Lyckholm beds in Estonia. The majority of the species of the family are recorded from the Wanwanian of Manchuria or from the Canadian of North America. The genera *Ribeiria* and *Ribeirella* are European, with the exception of *Ozomia* Walcott (probable synonym of *Ribeiria*), while *Ischyrinia* is known with one American and one European species and *Technophorus* with 12 Middle and Upper Ordovician species from North America.

Very little is known about the systematical position of the group. Apparently they represent Crustacea though the appendages are not known, but whether they can be placed in any of the orders recognized to-day is questionable. As this group became extinct in the Cincinnatian, they should be considered their own branch of primitive Crustacea as suggested by Kobayashi (1933).

THE NORWEGIAN MATERIAL

Two species which might be referred to the *Ribeiriidae* are present in the material at hand. One is a small, thin-shelled, elongate form, to some extent like *Ribeirella* Schubert and Waagen, but which I think more properly should be placed in the genus *Technophorus* Miller. The other is a rather large, thick-shelled species with deep scars of the clavicles on both sides of the umbo. This last species is so strikingly like *Ischyrinia* Billings that it must be referred to this genus in spite of some characters which differ from the descriptions of the two species hitherto known.

Genus *Technophorus* Miller, 1889

North American Geology and Palaeontology, p. 514.

Type of genus: T. faberi Miller, 1889.

This genus comprises rather curious species where the beaks of the two valves form a single pyramidal prominence on the casts (Ulrich, 1894, p. 613). Otherwise the rostrate form of the carapace with one ot two curved keels with slight concavities above, and the difference of the sculpture on the anterior and posterodorsal parts of the valves, are good characters. *Ribeirella* Schubert and Waagen, 1903, described as a genus of *Apodidae*, is considered a synonym by Clarke (1904). One specimen, which certainly should be placed in this genus, was among the better preserved fossils and is therefore described here. So far I know, this is the first record of *Technophorus* from Europe.

Technophorus stoermeri n.sp.

Plate I, fig. 1.

Name: I have the honour to name this species after Prof. Dr. Leif Størmer of the University of Oslo.

Holotype: One left valve, P.M.O. no. 5849. Leg. Th. Vogt.
Type locality: Ostøya, Bærum.
Type horizon: 4bβ (possibly δ).

Diagnosis: Carapace small, compressed, elongate, inequilateral, with a distinct long rostrum. Anterior margin (missing) apparently evenly rounded, ventral margin convex, dorsal margin forms two straight parts with a slight curvature inbetween. Umbonal clavicles not seen. Umbones (missing) in the anterior $\frac{1}{4}$ or $^1/_5$, a distinct keel or fold of the carapace starts near the umbo and runs in a slight curve to the posteroventral margin, where it broadens. The upper part seems to have been torn away and the lighter stone beneath forms a greyish white slit through the surface. There are some indefinite tubercle-like irregularities along the keel. There is a marked depression on the dorsal side of the keel and partly also on the ventral side. A second dorsal keel is seen in the middle of the posterodorsal part, especially distinct posteriorly with a slight concavity above, otherwise it slopes rather steeply to the dorsal margin. Posterior margin of the rostrum ends on the dorsal keel in an angle of 90°.

Sculpture on surface in front of keel consists of raised, concentric lines, close-set in the older part of the valve, more distant towards the margin. The interspaces are broader than the lines, of which 19 could be counted. Between the keels there are also traces of faint lines, but the dorsal slope is smooth.

Dimensions of the holotype: Length 6.3 mm, height 2.5 mm.

Remarks: Technophorus stoermeri bears a resemblance to *Ribeirella sharpei* (Barrande) Schubert and Waagen, 1903, but the latter is higher and has a more compressed dorsal part.

Genus *Ischyrinia* Billings, 1866

Cat. Sil. Foss. Anticosti. Geol. Survey of Canada, 1866, p. 16 and p. 52.

Type of genus: I. winchelli Billings, 1866.

The character which is most conspicuous of this genus, is the two strong interior ridges which radiate from the beak on both sides. Further, the carapace is elongate triangular with the anterior end short and round, and the surface marked by a number of radial lines (Kobayashi, 1933). The original diagnosis contains the word "equivalve" indicating that Billings supposed there were two valves. Ulrich (1894, p. 13, footnote) however, who has studied the type of *I. winchelli*, says that the evidence is fairly conclusive that the beaks were united in casts as in *Technophorus*.

Apparently Billings oriented his specimens in such a way that the radiating striae and the more truncated margin were considered to represent the anterior side (cf. Kobayashi, 1933, pl. X, figs. 13a-c.) while Teichert (1930) and Kobayashi (1933) in his diagnosis apparently reversed the position.

Ischyrinia norvegica n.sp.

Plate I, fig. 2, 3.

Holotype: Internal cast of a right side, P.M.O. no. 38267. Leg. J. Kiær, 1896.

Type locality: Furuberget, Hamar.
Type horizon: Cyclocrinus shale, 4b.

Material: Sample no. 38267 contains one cast of the right side (holotype) and one defective cast of the left side. Another sample (no. 37861) from the same locality, legit O. Holtedahl 1907, contains one cast of the right side and one mould of the left side; both are slightly shorter than the holotype, about 15 mm.

Diagnosis: Carapace convex, nearly equilateral, umbo bluntly pointed, slightly turned backwards. Anterior margin rounded, ventral margin evenly convex, posterior margin nearly straight, posteroventral corner distinct, and posterodorsal margin straight. Posterior part broader than the anterior part but slightly longer. Anterior and posterior clavicles strong, the anterior one curved, continuing in a shallower, nearly horizontal slight ridge which forms a low connection between the two clavicles, the posterior clavicles straighter and broadest dorsally, bordered posteriorly by a sulcus separating the clavicle from a ridge which is extended to the middle of the posterior margin and there divided into two ridges by a median sulcus. These sulci and ridges are naturally reversed on the cast.

Dimensions of the holotype: Length 16.4 mm, height 11 mm, semidiameter about 2 mm.

Remarks: This species is quite different from *I. winchelli*, but resembles to some degree *I. schmidti* Teichert, 1930, which, however, has a longer anterior part.

Conchostraca

One sample containing a small, bivalved pelecypod-like specimen, which must have had a very thin shell, and two other samples not so well preserved, seem to be referable to the order *Conchostraca*. Professor L. Størmer was so kind as to send two of these specimens to Dr. Nestor Novojilov, Moscow, whose opinion was that they belonged to the superfamily *Cyzicoidea* Stebbing and to the family *Glyptoasmussiidae* Novojilov, 1958.

True conchostracans are, however, not found earlier than Lower Devonian, and they are freshwater forms, except the one genus *Rhabdostichus* Raymond, 1946, which has been found in marin strata, possibly of Silurian age, but it may be Devonian.

Many marine Cambrian species have been described as conchostracans, (*e.g.* Ulrich and Bassler, 1931) but they are not considered true conchostracans by Raymond (1935, 1946). A few species, however, belonging to the genera *Lepiditta* Matthew (= "*Leperditta*" of Raymond) and *Fordilla* Walcott, are considered as possible ancestors of *Conchostraca* by Raymond (1946, p. 304). These are of Lower and Middle Cambrian age. As there existed a rich and differentiated fauna of conchostracans in Devonian times, one must expect to find pre-Devonian forms also.

To place the specimens from the Middle Ordovician in one of the younger genera containing freshwater forms is not advisable. To create a new genus seems to be the only solution, though characters separating it from other genera are vague. All relationships concerning these bivalved crustaceans are of course obscure as only the carapaces are known, and the classification must only be used as a practical tool until more is known of the animals.

Eoasmussia n.gen.

Type of genus: Eoasmussia heintzi n.sp.

Diagnosis: Carapace thin, ovate, somewhat inequilateral, anterior and posterior margins rounded, and continuing in the convex ventral margin. Dorsal margin probably nearly straight with large, more or less projecting umbones. The surface is ornamented with numerous raised concentric lines.

Eoasmussia heintzi n.sp.

Plate I, figs. 4, 5.

Name: I have the honour to name this species after Prof., Dr. A. Heintz of the Palaeontological Museum, Oslo, who collected the type specimen.

Holotype: P.M.O. no. 18901. Leg. A. Heintz 1933—34.
Type locality: Slependen, Asker, at the new Drammensvei.
Type horizon: Lower Chasmops shale, 4bα.

Material: Besides the sample containing the holotype there is another sample (P.M.O. no. 72039) from the roof of the tunnel W. of Billingstad, Asker, 4bα, leg. N. Spjeldnæs, 1958. Further there is a valve (P.M.O. no. 8258) from Juern, below Frok, Ringerike, Lower Chasmops limestone, 4bβ, leg. J. Kiær, which probably belongs to a related species.

Diagnosis: Carapace small, thin, ovate, not much inflated, the two sides of equal size, inequilateral, umbones before the middle, apparently not projecting beyond the hinge line. Anterior margin semicircular from the umbo to the convex ventral margin. Posteriorly subrostrate with rounded posterior margin, posterodorsal margin slightly convex. A decided concavity along the hinge line from umbo towards the posterodorsal corner. Sculpture consists of numerous regularly spaced concentric lines nearly as broad as the interspaces. Microsculpture invisible.

Dimensions of the holotype: Length 7 mm, height 5 mm.

Remarks: So far I know these remains of *Conchostraca* are the first recorded from Ordovician strata and may therefore be of more than local interest. The vague characters do not allow a distinct description, but the figure of the holotype (pl. I, fig. 4) certainly will be helpful when this species is compared to the new material which undoubtedly will be found in the coming years. The specimen from Billingstad (pl. I, fig. 5) is not complete and probably somewhat distorted, but the number and course of the concentric lines agree fairly well with the holotype. Both samples are from the Lower Chasmops shale, 4bα, and therefore more or less contemporaneous. The third specimen, from Juern (pl. I, fig. 6) is from 4bβ, and apparently belongings to another species. The concentric lines are narrow and sharp, and the interspaces are much broader than the lines. The characters are, however, so indistinct that I have refrained from describing it.

List of species and their occurrence

NOTOSTRACA

Technophorus stoermeri n.sp. — 4bβ (possibly δ) — Oslo—Asker.
Ischyrinia norvegica n. sp. — Cyclocrinus beds — Hamar—Nes.

CONCHOSTRACA

Eoasmussia heintzi n. gen. et sp. — 4bα — Oslo—Asker.
Gen. et sp. indet. — 4bβ — Ringerike.

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Manuscript received September 8, 1959.
Printed June 1960.

PLATE I.

Specimens whitened with ammonium chloride. Photographs not retouched.

Fig. 1. *Technophorus stoermeri* n.sp. Holotype. Left valve from Ostøya, Bærum, 4bβ, P.M.O. no. 5849. Length 6.3 mm. x 10 — p. 126.

Fig. 2. *Ischyrinia norvegica* n.sp. Holotype. Internal cast of right side from Furuberget near Hamar, Cyclocrinus beds, 4b, P.M.O. no. 38267. Length 16.4 mm. x 3 — p. 127.

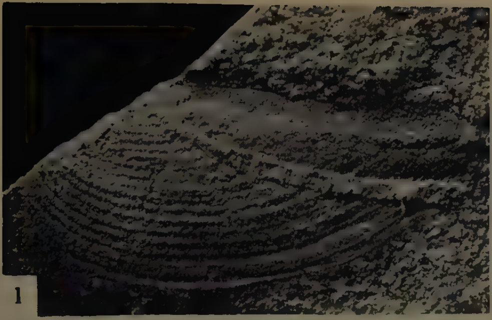
Fig. 3. *Ischyrinia norvegica* n.sp. Paratype. Mould of left side from Furuberget near Hamar, Cyclocrinus beds, 4b, P.M.O. no. 37861. Length 15 mm. x 3 — p. 127.

Fig. 4. *Eoasmussia heintzi* n.gen. et sp. Holotype. From Slependen, Asker, 4bα, P.M.O. no. 18901. Length 7 mm. x 6 — p. 129.

Fig. 5. *Eoasmussia heintzi* n.gen. et sp. From Billingstad, Asker, 4bα, P.M.O. no. 72039. Length 5.5 mm. x 6.8 — p. 129.

Fig. 6. Conchostraca sp. From Juern, Ringerike, 4bβ, P.M.O. no. 8258. Length 4.3 mm. x 11.4 — p. 129.

PLATE I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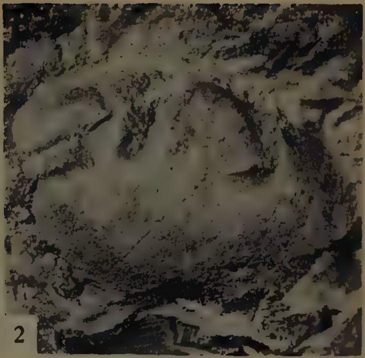
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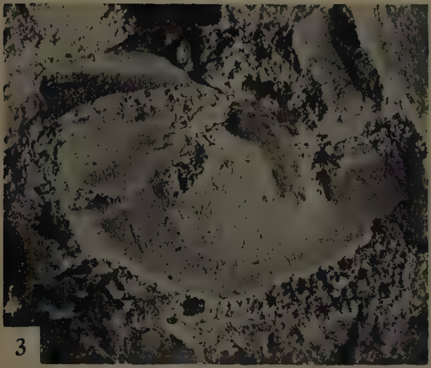
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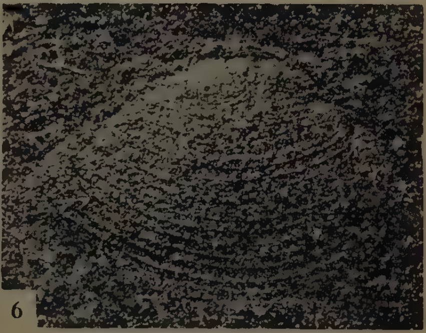
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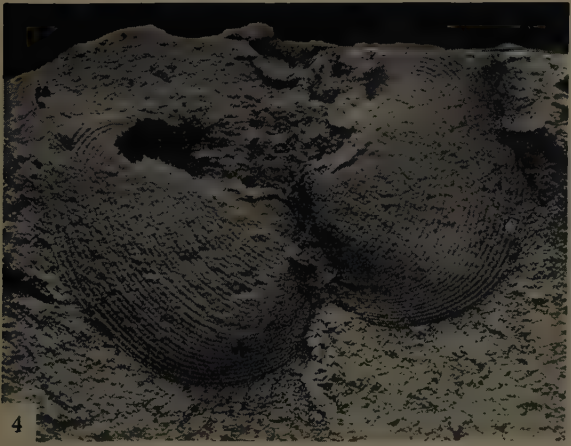
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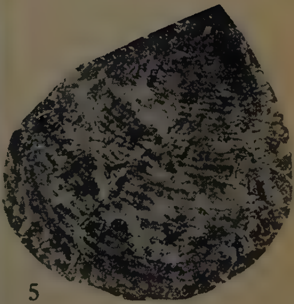
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CONTRIBUTIONS TO THE MINERALOGY OF NORWAY

No. 5. Trace element variations in three generations of feldspars from the Landsverk I pegmatite, Evje, southern Norway.

By

S. R. Taylor[1], K. S. Heier[2] and T. L. Sverdrup[3]

Abstract: Li, Na, K, Rb, Cs, Pb, Tl, Ca, Sr and Ba have been determined in potassium feldspars and coexisting albites of three different generations from one large pegmatite (Landsverk I, Evje, southern Norway). In addition Fe, Cr, Mn, Cu, Co, Ni, V, Sn and F were determined in a pink microcline and a green amazonite which were seen to grade into each other.

Some element concentrations and ratios reflect the different conditions of formation of the feldspars from the three generations. The data indicate that the amazonite formed through metasomatic action of a "pegmatitic rest liquid" (from which cleavelandite crystallised) on the pink microcline of the first generation. The trace element data also indicate that the youngest K- feldspar is not a late fractionation product of the pegmatite, but rather a late secondary mineralisation.

The cause of the colouring of the amazonite is discussed and it is concluded that it is not to be found in a significant difference in composition from the pink microcline for any of the elements determined.

Introduction.

Two of the authors (K. S. H. and S. R. T.) have made previously an extensive study of the distribution of trace elements in K-feldspars from a variety of pre-Cambrian basement rocks from southern Norway (Taylor and Heier; 1958 a, b, 1960; Heier and Taylor,

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1959 a, b). Rock types studied included gneisses, augengneisses, anatexe granites, diapire granites, and small and large pegmatites. Extreme fractionation trends were discovered in the trace elements of the feldspars from large pegmatites. The present investigation of feldspars of different generations was undertaken to see whether these same trends would be useful in elucidating the history of a single large pegmatite, and if it would be possible to distinguish between feldspars of different generations by the trace element data.

Another aim of this study was to investigate the relations between the trace element contents of the different generations to establish whether they were genetically related in a single fractionation sequence, or whether the later generations were derived from replacement, either by solutions from within the pegmatite, related to earlier feldspars, or from a separate mineralisation. By this approach it was hoped to shed some light on the complexities of mineral paragenesis in pegmatites as discussed by many authors; for a selected bibliography and discussion, see JAHNS (1955).

Location and geological description.

The pegmatite Landsverk I, Evje, south Norway, is one of the numerous pegmatites occurring in the pre-Cambrian basement rocks of southern Norway (Fig. 1). It is located close to the road about 500 metres NNW of Landsverk. The pegmatite is described by ANDERSEN (1926, 1932) and BJØRLYKKE (1935). According to ANDERSEN the pegmatite has produced 20,000 tons of feldspar and more than 1000 tons of quartz. Mining was discontinued in 1928 but commenced again in 1958. The pegmatite occurs in a dark gabbroic (amphibolitic) rock. It strikes EW and the contacts toward the enclosing rock are irregular with apparent vertical dip. Part of the pegmatite is brecciated, the breccia consisting of fragments of pegmatite and the surrounding gabbro, cemented with quartz. The pegmatite extends for about 120 metres along the strike. It appears to pinch out towards the east and disappears under overburden towards the west. It has been mined for about 100 metres along the strike to a width of 10 to 20 metres, and in places to a depth of 10 metres. The feldspars examined by us are mainly taken from the dumps, but their position in the pegmatite can be deduced.

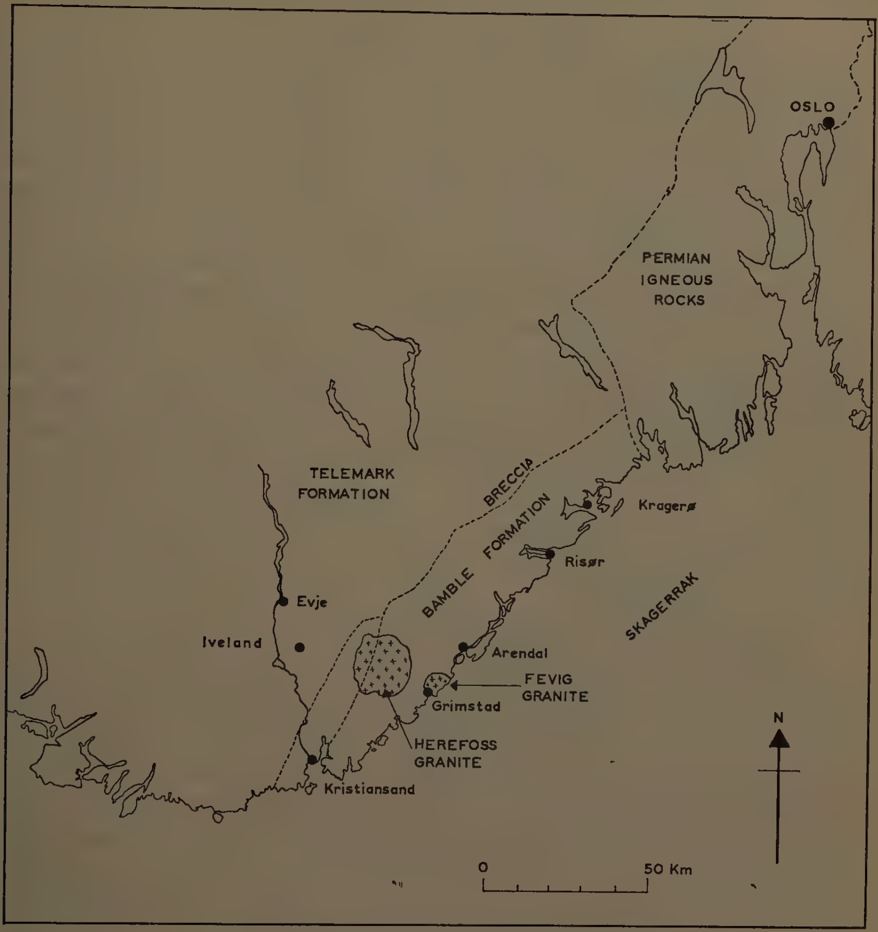

Fig. 1. Map showing the location of Evje.

The common minerals in the pegmatite are: quartz, potash feldspar, (often as large crystals several metres long), plagioclase (in small amounts compared to potash feldspars), biotite and muscovite. Less common minerals are: monazite, fergusonite and euxenite which occur with the mica. ANDERSEN also records the presence of uraninite, orthite, epidote, garnet, magnetite, calcite and the zeolite mineral leumontite.

The feldspar minerals.

Alkali feldspars of different colours are characteristic of the pegmatite, and it was the recognition of these which started the present study. Albite occurs with all the different coloured potash feldspars. On the basis of field evidence and thin section studies, the following sequence of feldspar generations has been established.

Generation 1. (G2) Pink microcline (10)[1] which is the common pegmatite feldspar. The other feldspars are rare by comparison. White plagioclase (16) occurs in association.

Generation 2. (G1) Amazonite (12). This feldspar has the characteristic green amazonite colour. A transition between the first generation microcline and the amazonite (Plate 2, Fig. 1) was sampled and analysed (Nos. 11.1—11.6). Cleavelandite occurs typically with the amazonite (17, 18).

Generation 3. (G3) "Brick red" microcline (14) occurs in the brecciated part of the pegmatite as:

a. coating on the surface of the other feldspars.
b. fillings along tiny cracks and fissures in the other feldspars.
c. replacing the albite lamellae of the other feldspars (13, 15).

A sugar grained albite (19, 20) often occurs intermixed with the G3 microcline and is assumed to be of the same age.

Potash feldspars of all three generations are microclines. Triclinicity values as indicated by X-ray powder methods (GOLDSMITH and LAVES, 1954) are approximately 0.80 for G1 and G2 feldspars. For the G3 feldspar the triclinicity value is as high as 1.10, indicating a much more ordered structure for the latter.

Samples 11.1 to 11.6 are different transitional stages between G1 and G2 feldspars. The samples were drilled out at 1 cm intervals from the same handspecimen (Plate 2, Fig. 1). The size of the albite lamellae is fairly large compared to the diameter of the drill holes so that the minor chemical differences between the six samples cannot be claimed to give the correct picture of the amazonite-microcline transition. However, From Fig. 2 it can be seen that these feldspars constitute a Na rich group of alkali feldspars. The pure amazonite (12) is high in Na. The microcline (10) plots in the albite poor end. Thus,

[1] Sample numbers in Tables 1 to 4.

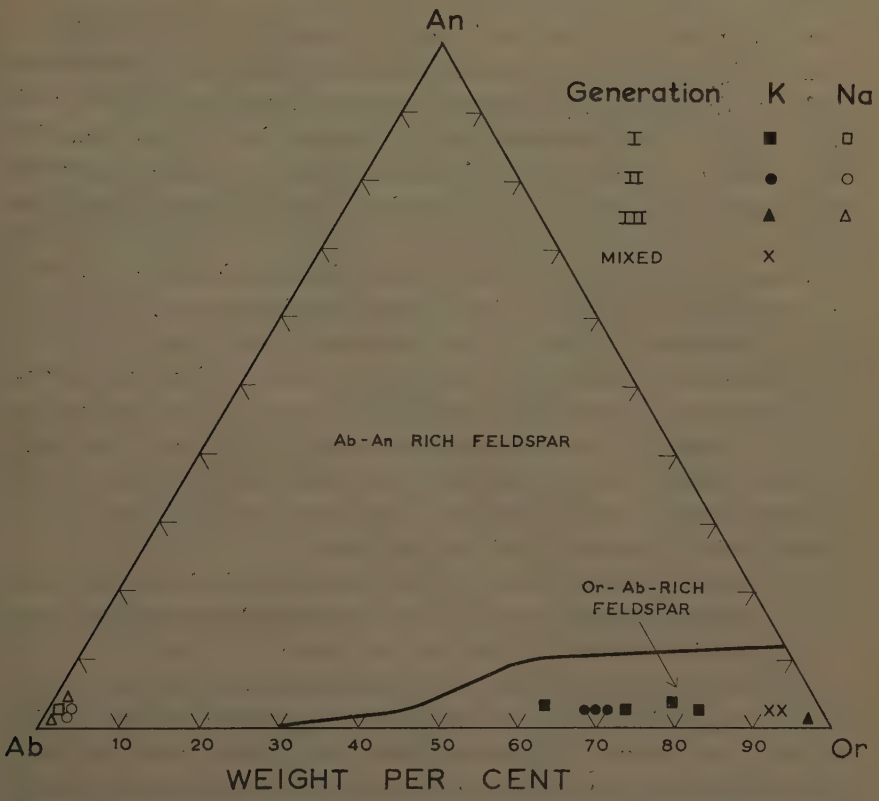

Fig. 2. Feldspar compositions from Table 3 plotted on the projection of the quarternary system Or-Ab-An-H_2O at 50 00 bars H_2O pressure (Yoder et al, 1957).

the amazonites are not lower in Na than the G1 microcline which would be expected if they crystallized of a pegmatite melt or vapour at lower temperatures than the G1 microcline.

Oftedal (1957) on the basis of heating experiments with amazonite, concluded that the "colour centra" in amazonite formed below 300° C, probably at about 250° C in already crystallized feldspar, and that this is in accordance with field observations which indicate that the green colour originated in connection with the formation of later cleavelandite veins. This association between amazonite and cleavelandite is always present in Norwegian pegmatites of which the authors have firsthand knowledge.

The very low Na content of the G3 microcline (Table 1, Fig. 2) shows this feldspar to have formed at very low temperatures (it occurs together with albite). This feldspar, besides occurring on cracks and as a coating on the other feldspars, is typically found to replace the albite lamellae in the other K- feldspars. Thus the albite associated with it may be recrystallised material of the albite lamellae in the older perthites.

In summary the following sequence of feldspar formation is used as a basis for the discussion of trace element distribution.

1. Crystallisation of microcline and albite of generation 1 (G1).
2. Crystallisation of the "pegmatitic rest liquid" to form cleavelandite, and metasomatic alteration of G1 microcline into amazonite (G2). An albitisation of the G1 plagioclase may have taken place simultaneously, but is difficult to prove. The G1 plagioclase (albite) contains no more Ca than the cleavelandite (Table 1).
3. Brecciation of a portion of the pegmatite.
4. Crystallisation of the generation 3 (G3) potash feldspar in cracks and replacing albite lamellae in G1 and G2 feldspars. Some albite is assumed to belong to this stage as well.

Many authors, for example SCHALLER (1927) and LANDES (1933) have discussed the role of replacement in pegmatites. JAHNS (1955) gives a summary of the various views. It will be shown later that the third generation feldspars are so unrelated in trace element composition to those of the preceding generations as to make a separate origin necessary. They cannot be considered as a late fractionation product related to the preceding generations, nor may they be derived from reaction of a rest liquid with the earlier formed crystals.

Sample preparation.

Methods of mineral separation and sample preparation were similar to those described previously (TAYLOR and HEIER, 1958 a; HEIER and TAYLOR, 1959 a).

To obtain samples from the specimen showing the transition from pink microcline to green amazomite, a series of drillings (11.1—11.6) 1 cm apart were made (see Plate 2, Fig. 1). These samples were found to be contaminated with Fe, Cu, and Ni, even after magnetic separation. Because of this contamination, three samples (11.7—11.9) for the determination of these elements were taken in the areas shown on Plate 2, Fig. 1. Maximum precautions were taken to avoid contact with metal. Because of this it was not possible to take a series of small samples similar to the drilled ones, and instead, one sample of the amazonite and two of the microcline were broken off from a sawed section about ¼" thick. A new chisel was used to break off the initial pieces along the cleavages. Edges which came in contact with the chisel were discarded and small cleavage fragments were crushed in a large agate mortar which had been cleaned with A. R. HCl and HNO_3. A hand magnet was used at this stage to extract any metal; none was observed. Samples were then ground in a mechanical agate mortar to pass 120 mesh Terylene bolting cloth held in Perspex holders. This powder was run through a Frantz magnetic separator set at 20° forward and 15° back tilt and 1.5 amp. current, but no magnetic fraction was observed to separate. It is believed that adequate precautions were taken to avoid contamination in these samples. That these are necessary is shown by the extreme difficulty of removing metallic contamination from the drilled material (samples 11.1—11.6). Repeated running of these samples through the magnetic separator and treatment with a hand magnet was unable to reduce the Fe contamination below about several hundred ppm. With drilled samples, of course, the metallic contamination is of very small particle size, and the mineral powder tends to adhere to the metallic nuclei.

Analytical methods.

(*a*) *The alkali elements.*

Na and K were determined by flame photometer. Li, Rb and Cs were determined by emission spectroscopy using DC arc anode excitation. The method was similar to previously published methods (TAYLOR and HEIER, 1958 a, HEIER and TAYLOR, 1959 a) except that Kodak IL plates were used in place of Kodak IIN. For the plagioclase feldspars, anodes with an internal diameter of 1/8" (3.2 mm) and a depth of 5 mm were used to increase sensitivity.

(*b*) *Lead, thallium, and copper.*

The method was similar to that described by HEIER and TAYLOR (1959 a) except that Kodak 103–0 plates were used in place of Ilford

N. 30. Slightly larger electrodes 1/8" (3.2 mm) internal diameter and 5 mm deep were used; the optical system comprised a Hilger E.958 lens focussed directly on the slit; K 3447,7 was used as internal standard line for K- feldspars and K 4044 for the plagioclase feldspars.

Samples 11.1 to 11.6 which were drilled from the sample shown in Plate 2, Fig. 1 were found to be contaminated by Fe, Ni and Cu. The nickel contamination was particularly serious for the determination of Tl since interference on Tl 3775.7 was observed by Ni 3775.6 (500 intensity listing in the MIT tables). The control line was Ni 3783.5 (500). This interference was observed in all the drilled samples (particularly in 11.4 and 11.5), but not otherwise. Tl 3519.2 was used to determine Tl in these samples; this line was fortunately resolved from Ni 3519.8 (500) which was also present in samples 11.1 to 11.6. No interference of Pb 4057 by Mn 4057 (80) was observed except for the standard granite G-1 (Ahrens and Fleischer, 1960). The control line was Mn 4058 (80). Critical timing of the exposure is of course necessary to avoid CN interference on Tl 3775 and Pb 4057. Copper was also determined in samples 11.7 to 11.9. Cu 3247 and 3274 were teh analytical lines.

(*c*) *Ca, Sr and Ba.*

These elements were determined in a similar fashion to the method described by Heier and Taylor (1959 b) except that Kodak 103–0 plates were used, and National Carbon Co. grade SP–2 graphite powder was used in place of Johnson- Matthey JM–9.

(*d*) *Cr, Fe, Mn, V, Co, Ni.*

Since sample 11 shows a transition from green amazonite to pink microcline, the opportunity was taken to see if any significant differences existed in the concentrations of various elements which have been suggested as being responsible for the green colour (see p. 152). Anodes were cut from 3/16" (4.8 mm) National Carbon Co. Special graphite (Cat. No. L.3806) and were 1/8" (3.2 mm) internal diameter by 5 mm deep. Cathodes were 1/8" (3.2 mm) National Carbon Co. special carbon (Cat. No. L.3863). Blank electrodes were arced on the same plates as the samples. The samples were mixed with two parts of the carbon-palladium mix used for the determination of Ca, Sr and Ba. (One part by wt. of Johnson- Matthey "Specpure" $((NH_3)_4$

Pd)$(NO_3)_2$ and nine parts of National Carbon Co. SP–2 graphite). The same arcing conditions were used as in the determination of Ca, Sr and Ba except that the optical system was changed to give maximum intensity (Hilger E.958 lens focussed on slit). Pd 4473 was the internal standard line. Fe 4326, Mn 4030 and Cr 4254 were read. V 4379 was not observed in any samples.

A detection limit of less than 1 ppm was obtained. An exposure was also made to cover the range from 2750 to 4650 Å using quartz optics, but Ni 3414 and Co 3453 were not detected in samples 11.7 to 11.9. It is believed that the conditions above were of sufficient sensitivity to have detected any cation present in amounts sufficient to cause the green çolouration.

(*e*) *Fluorine.*

The samples were mixed with one part of Johnson-Matthey "Specpure" $CaCO_3$ and one part of National Carbon Co. SP–2 graphite powder and arced at 3 amp DC using anode excitation. A Hilger large quartz and glass spectrograph was used with glass optics. Ilford HP3 plates were employed. Lower electrodes were cut from National Carbon Co. Special Graphite Spectroscopic (Cat. No. L3806) 3/16" rod. The crater was 1/8" (3.2 mm) diameter and 2 mm deep. Upper electrodes (cathodes) were 1/8" (3.2 mm) National Carbon Special Carbon rod (Cat. No. L.3863). The bandhead CaF 5291 was used. The standard granite G–1 (700 ppm F) and the standard diabase (200 ppm F) (AHRENS and FLEISCHER, 1960) served as standards.

Analytical data.

The concentrations of the elements determined are given in Table 1, and the calculated theoretical feldspar compositions in Table 3. Table 3 shows that Or. Ab. and An. are the only feldspar components present in amounts greater than 1 per cent. The Ba- feldspar is in one case (14) as high as 0.97 per cent, but is typically much less. The Rb- feldspar component is typically next in importance after Or, Ab. and An, ranging between 0.22 and 0.67 per cent. Or,, Ab., and An. may be regarded as major elements in the feldspar structure, and their concentrations govern the distribution of the other elements (see HEIER and TAYLOR, 1959 b). The feldspars are plotted on the

Table 1. Analytical data for feldspars from Landsverk I pegmatite. (n d = not detected).

Sample No. (K-feldspars)	Generation	Li ppm	Na %	K %	Rb ppm	Cs ppm	Pb ppm	Tl ppm	Ca %	Sr ppm	Ba ppm
10 (131d)	1	1.1	1.25	11.26	980	n d	300	11	0.35	33	235
11.1 (429.6)	1	1.0	3.15	8.67	960	32	110	24	0.47	140	235
11.2 (429.5)	1	0.8	1.54	10.96	1130	39	135	27	0.50	92	155
11.3 (429.4)	1	0.8	2.17	10.15	1130	37	125	29	0.39	70	105
11.4 (429.3)	2	0.7	2.55	9.55	1110	53	245	73	0.33	34	27
11.5 (429.2)	2	0.6	2.55	9.55	980	50	115	38	0.27	41	28
11.6 (429.1)	2	1.2	2.41	9.78	1370	54	76	33	0.26	36	35
12 (131a)	2	0.6	2.61	9.48	1170	70	115	99	0.38	54	55
13 (137b)	2–3	1.8	0.37	12.97	1210	74	99	65	0.40	105	380
14 (137e)	3	1.9	0.25	13.45	580	n d	1.4	8.9	0.22	43	3550
15 (137a)	1–3	2.4	0.61	12.77	890	n d	115	10	0.28	27	640
(Na-feldspars)											
16 (134b)	1	0.4	8.42	0.23	19	n d	13	1.0	0.51	53	19
17 (131b)	2	0.6	8.52	0.31	92	7.0	43	1.2	0.87	62	49
18 (501)	2	0.5	8.31	0.31	67	6.9	23	1.4	0.21	15	25
19 (133a)	3	0.3	8.31	0.15	7.9	n d	5.9	1.1	0.43	36	16
20 (500)	3	0.4	8.61	0.14	9.5	n d	5.0	0.7	0.16	13	12

Table 2. Sample numbers and descriptions of feldspars from the Landsverk I pegmatite.

Sample no.	Generation	Description of samples
10 (131d)	1	Reddish brown (pink) microcline, parts of which are covered on the surface by G3 microcline. Care was taken to avoid contamination. Coexists with plagioclase (16).
11.1 (429.6)	1	G1 microcline.
11.2 (429.5)	1	
11.3 (429.4)	1	
11.4 (429.3)	2	Fig. 2. Transition between G1 and G2.
11.5 (429.2)	2	
11.6 (429.1)	2	G2 microcline (amazonite).
12 (131a)	2	Typical green amazonite occurring in contact with and in assumed equilibrium with cleavelandite (17).
13 (137b)	2–3	Green amazonite which is partly replaced by G3 microcline. The latter appears to replace preferentially the albite lamellae in the amazonite.

Table 2. (Cont.)

Sample no.		Generation	Description of samples
14	(137e)	3	"Brick red" microcline which occurs as a coating on G1 microcline. This type also occurs penetrating and replacing G1 and G2 microclines (13 and 15). It also occurs intergrown with white "sugar-grained" albite (19).
15	(137a)	1–3	Typical G1 microcline which is partly replaced by G3 microcline.
16	(134b)	1	White plagioclase crystals occurring with G1 microcline (10).
17	(131b)	2	Cleavelandite of very weak bluish colour, in contact with amazonite (12).
18	(501)	2	Light blue "sugar grained" plagioclase, not in contact with microcline, but chemically and physically similar to cleavelandite (17).
19	(133a)	3	White "sugar grained" albite intergrown with G3 microcline (14).
20	(500)	3	Light blue "sugar grained" albite not in contact with microcline but chemically similar to G3 plagioclase (19).

projection of the quaternary system Or., Ab., An., H_2O at 5000 bars water vapour pressure (YODER et al, 1957) in Fig. 2. The potash feldspars show a wide spread in composition from Or. 61 to Or. 96, whereas the coexisting plagioclases have a rather uniform composition of about An. 1 to 5.

Lithium, Tin, Beryllium and Fluorine.

Lithium is present in nearly all the feldspars, but always in very small amounts. It averages 1.2 ppm in the potash feldspars in good agreement with the average of 1 ppm found by HEIER and TAYLOR (1959 a). The plagioclases contain less Li, averaging 0.43 ppm. The G3 microcline and the G1—G3 and G2—G3 mix are higher in Li than the other feldspars.

OFTEDAL (1957) suggested that the new elements introduced into the pegmatite during the formation of the cleavelandite were chiefly F, Li, Be, Sn. No introduction of Li is indicated in our samples. Tin and beryllium were not detected in any samples. The detection limit

Table 3. Theoretical feldspar "molecules" calculated from analytical data.

Sample no. (K-feldspars)	Ab	Or	RbAl Si_3O_8	CsAl Si_3O_8	$PbAl_2$ Si_2O_8	TlAl Si_3O_8	An	$SrAl_2$ Si_2O_8	$BaAl_2$ Si_2O_8	Sum
10 (131d)	14.25	80.14	0.29	—	0.06	0.002	2.43	0.012	0.064	97.25
11.1 (429.6)	35.9	61.70	0.36	0.009	0.024	0.005	3.26	0.052	0.064	101.38
11.2 (429.5)	17.56	78.00	0.43	0.011	0.029	0.006	3.47	0.034	0.042	99.58
11.3 (429.4)	24.74	72.24	0.43	0.010	0.027	0.006	2.71	0.026	0.029	100.22
11.4 (429.3)	29.07	67.97	0.42	0.015	0.053	0.016	2.29	0.013	0.007	99.85
11.5 (429.2)	29.07	67.97	0.37	0.014	0.025	0.008	1.87	0.015	0.008	99.35
11.6 (429.1)	27.47	69.60	0.52	0.015	0.016	0.007	1.80	0.013	0.010	99.45
12 (133a)	29.75	67.47	0.67	0.020	0.025	0.021	2.64	0.021	0.015	100.63
13 (137b)	4.22	92.31	0.46	0.021	0.021	0.014	2.78	0.039	0.10	99.97
14 (137e).......	2.85	95.72	0.22	—	—	0.002	1.53	0.016	0.97	101.31
15 (137a)	6.95	90.88	0.59	—	0.025	0.002	1.94	0.010	0.18	100.58
(Na-feldspars) .										
16 (134b)	95.99	1.64	0.01	—	0.003	—	3.54	0.020	0.005	101.21
17 (131b)	97.13	2.21	0.035	0.002	0.009	—	6.04	0.023	0.013	105.46
18 (501)	94.73	2.21	0.025	0.002	0.005	—	1.46	0.006	0.007	98.45
19 (133a)	94.73	1.07	0.003	—	0.001	—	2.98	0.013	0.004	98.80
20 (500)	98.15	0.99	0.004	—	0.001	—	1.11	0.015	0.003	100.26

is difficult to set precisely, but is not greater than 50 ppm. Fluorine was not detected in the amazonite (11.7), nor in accompanying microcline (11.8 and 11.9) (Plate 2, Fig. 3). The detection limit is about 100 ppm.

Rubidium.

The behaviour of Rb in potash feldspars from the pre-Cambrian basement rocks, including pegmatites, from southern Norway is discussed by HEIER and TAYLOR (1959 a). Fig. 3 shows plots of ppm Rb vs. per cent K for the Evje pegmatite feldspars. The first generation microclines and albites have K/Rb ratios which fall just within the limits of "normal" ratios. (For discussions of the significance of "normal" and "anomalous" or "abnormal" K/Rb ratios, see TAYLOR et al, 1956, TAYLOR and HEIER, 1958 a and b; HEIER and TAYLOR 1959 a). The third generation microcline and albite likewise have "normal" K/Rb ratios. It will be seen readily from Fig. 3 that in each case the K- feldspar and the coexisting albite have similar ratios (within the limits of precision of the data), and that the G3 feldspars contain distinctly less Rb (higher K/Rb ratios) than those of the first generation. Sample 15, a mixture of G1 and G3 feldspars, has a ratio intermediate between them. The amazonite (G2) is somewhat enriched in Rb, as are the transitional stages between the microcline and the amazonite (11.1—6).

The second generation cleavelandite (17, 18) is likewise enriched in rubidium. This is the first well authenticated case of a plagioclase feldspar displaying enrichment in rubidium relative to potassium. The K and Rb spectra are shown in Plate 1. The spectra of the other plagioclases and the standard diabase W–1 (AHRENS and FLEISCHER, 1960) are shown for comparison.

Three possibilities exist to account for the Rb enrichment in a plagioclase: (a) The cleavelandite crystallised from a medium enriched in Rb (and Cs, see next section) and these elements were able, with K, to enter the lattice in proportions comparable to their concentrations in the liquid. (It is difficult to devise a reasonable process to enrich Rb and Cs selectively, relative to K, in the albite lattice).

(b) The Rb (and Cs) concentrations come from intergrowths of amazonite. The low bulk content of potassium does not support this explanation. No such intergrowths were visible in thin sections.

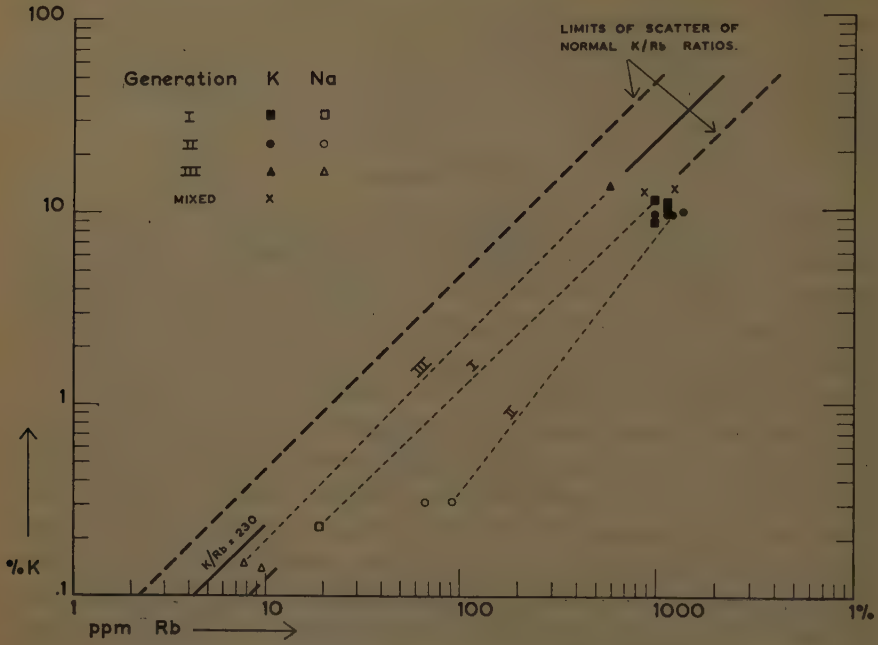

Fig. 3. K/Rb relationship. The similarity of K/Rb ratios for plagioclase and K- feldspars of the same generation should be noted. Generation 2 plagioclase (Cleavelandite) has slightly lower K/Rb ratios than the coexisting amazonite (see text).

(c) Adequate precautions to avoid contamination with the amazonite were taken, and in any event the K/Rb ratio of the cleavelandite is lower than that of the amazonite. This may also be seen from Fig. 3. The fact that the cleavelandite is relatively richer in Rb than the coexisting amazonite is in accord with the suggestion that the amazonite results from the action of the cleavelandite liquid on the first generation microcline. It is interesting to observe that the albite lattice is able to accomodate Rb and Cs (see next section) in amounts greater than normal. The concentration levels are of course, low; this may enable the crystal to reflect the composition of the liquid from which it is crystallising without apparent rejection of the larger ions: in any events there seems to be no selective effect based on the lower coordination of Na in albite compared with K in K- feldspar (TAYLOR and HEIER, 1958 b).

The relatively low amount of Rb in the third generation feldspars indicates that they are not derived from the "residual pegmatitic liquid", in which the Rb content would be expected to increase over that in the second generation. From the evidence of the K/Rb ratios, the G3 feldspars are not connected genetically with those of the preceding generations.

Cesium.

Cesium has a distribution pattern very similar to that of Rb in the Evje pegmatite, and its distribution can be interpreted in the same way. In the K- feldspars the Cs concentrations are high in G2

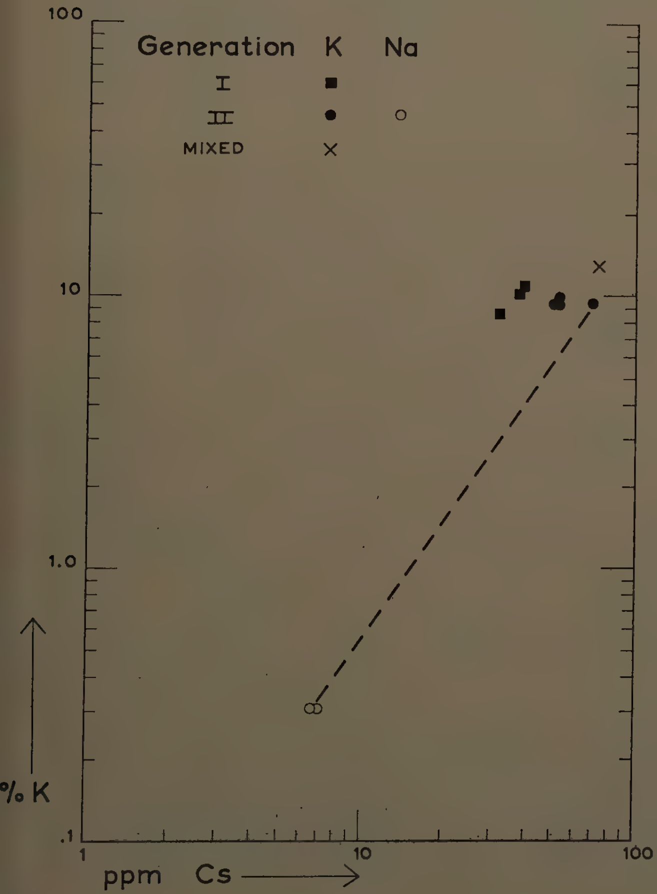

Fig. 4. K/Cs relationship. The cleavelandites have the same K/Cs ratio as the amazonites. The other plagioclases do not contain detectable Cs (< 2 ppm) and hence have much greater K/Cs ratios than the coexisting K- feldspars.

(70 ppm), not detected in G3, and not detected or low in G1. The G1—G2 transitions are intermediate in Cs content between the pure members, ranging from 32 to 54 ppm.

The presence of cesium in the cleavelandite is noteworthy. It was not detected in the other albites. The K/Cs ratio in the cleavelandites is 446 and is less than the K/Cs ratio of 1354 in the coexisting amazonite. The relative enrichment of Cs in the cleavelandite compared to the amazonite is very similar to that for rubidium. This can be easily seen from Figs. 3 and 4 where the slope of the cleavelandite-amazonite join for Cs is 56° (Fig. 4) and for Rb 53° (Fig. 3). Thus both the K/Rb and K/Cs ratios indicate that the cleavelandite is more highly fractionated than the amazonite. There is, of course, a considerable degree of enrichment in Cs compared with the abundant crustal rocks, where K/Cs ratio is commonly about 7000 (AHRENS, EDGE and TAYLOR, 1960).

Lead.

The first generation K- feldspar has the high lead content typical of pegmatite feldspars. WEDEPOHL (1956) found an average of 100 ppm in K- feldspars from pegmatites compared with an average of 25 ppm in K- feldspars from normal igneous rocks. The amazonite is slightly lower in lead than the G1 microcline, but the third generation feldspar is distinctly low in Pb.

The first generation albite contains 13 ppm lead. WEDEPOHL (1956) found an average of 10 ppm for albite, with some cleavelandites containing up to 32 ppm. Our cleavelandites, coexistent with the amazonite, contain 23 and 43 ppm Pb. HEIER (1960) found the Pb content of the plagioclases to be similar to or slightly higher than that of coexisting K- feldspars in amphibolite and granulite facies rocks. The distribution of lead in the Evje pegmatite feldspars is rather similar to rubidium and cesium. The geochemical behaviour of lead in K- feldspars has been interpreted by TAYLOR and HEIER (1960) mainly in terms of relative bond strengths. Lead tends to be concentrated in the later fractions. Divalent strontium of nearly the same size, is enriched in the earlier fractions, and its behaviour can, to a first approximation, be explained by the classical principle of capture (HEIER and TAYLOR, 1959 b). The contrasted behaviour of lead is attributed to the more covalent character of the Pb–O bond.

Thallium.

Tl+ is the same size as Rb+. AHRENS (1948) showed a close coherence between Rb and Tl to exist in rocks. HEIER and TAYLOR (1959 a) in an investigation of K- feldspars from the pre-Cambrian basement rocks of southern Norway found that Tl became enriched with respect to Rb as fractionation proceeded. This was shown by the steeper slope of the Tl–Rb plot in our case compared with that of AHRENS (1948). In particular, the large pegmatite feldspars were enriched in Tl with respect to Rb. This behaviour, which is similar to that of cesium, has been ascribed by TAYLOR and HEIER (1960) to the more covalent character of the Tl–0 bond compared to the Rb–0 bond. The larger size of cesium is the cause of its enrichment in the later fractions.

Figure 5 shows a plot of Tl against Rb. It should be compared with Fig. 8 of HEIER and TAYLOR (1959 a). Tl is relatively enriched, compared to Rb, in the amazonite, and in the G1—G2 and G2—G3 transitions. The first and third generation feldspars have normal amounts of Tl for the amount of Rb present.

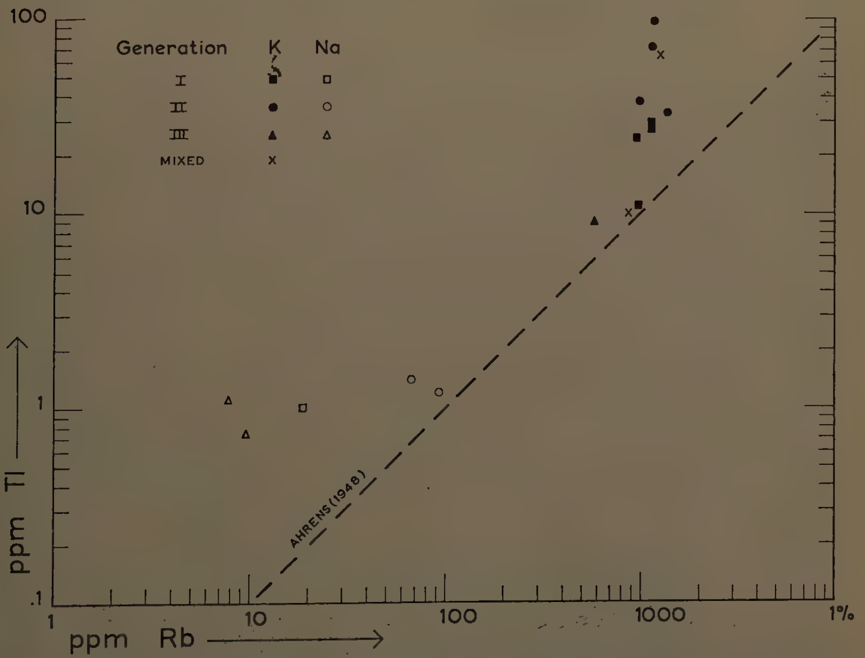

Fig. 5. Rb/Tl relationship. The average line of the Rb/Tl diagram from Ahrens (1948) is shown for comparison.

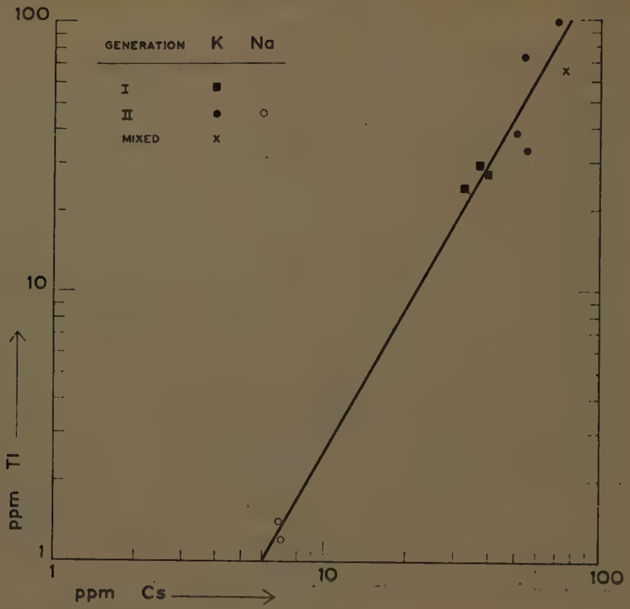

Fig. 6. Tl/Cs relationship. A close association is seen.

The Na- feldspars have the low amounts of Tl typical of the group, and the levels are comparable to published data (AHRENS, 1948; SHAW, 1952, 1957). In view of the fractionated character of the cleavelandites their low Tl content is surprising. SHAW (1952) gives a value of 6.8 ppm for a cleavelandite and this sample was available to us as a standard through the courtesy of Dr. D. M. Shaw. We can find no adequate reason to account for the low Tl content in our samples. If the cleavelandite lattice can accomodate Cs, there seems no reason why it should not accomodate Tl at a level of a few ppm.

Fig. 6 shows the Tl—Cs relation. In those samples where both elements were detected, a moderately close relationship exists. Compared to cesium, the amazonites show slight enrichment in Tl. This effect is also shown by the G1—G2 transition samples.

Calcium, Strontium and Barium.

The distribution of Ca, Sr and Ba in K- feldspars has been discussed by HEIER and TAYLOR (1959 b). They found in a fractionation series the sequence of entry of these elements in K- feldspars to be

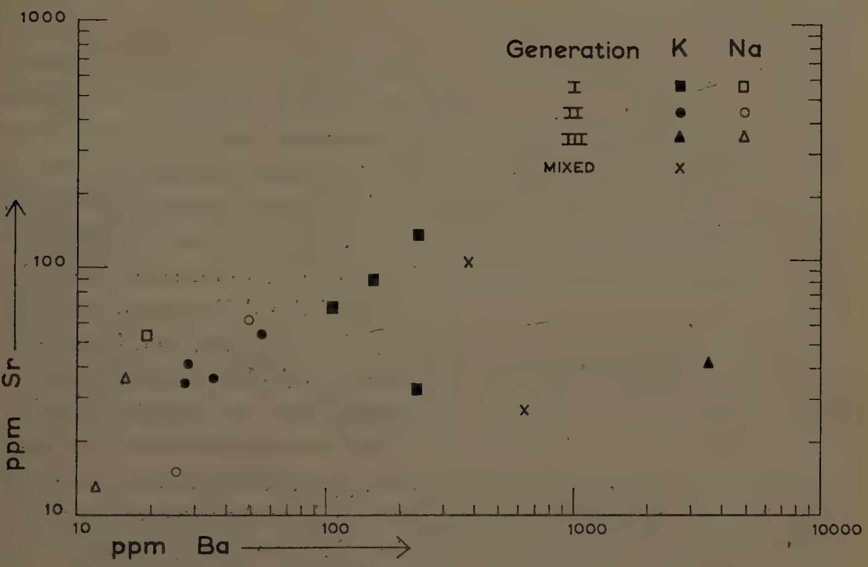

Fig. 7. Ba/Sr relationship.

in the order Ba, Sr, Ca, so that Ba decreases more rapidly than Sr, and Sr more rapidly than Ca, so that the Ba/Sr and Sr/Ca ratios both decrease with increasing fractionation. This was explained in terms of the relative strength of the Ba–0, Sr–O and Ca–0 bonds.

Plots of ppm Ba vs. ppm Sr in the Evje pegmatite feldspars are shown on Fig. 7. There is no correlation between the Ba/Sr ratios of the K-feldspars from the different generations. The unique position of the G3 microcline is indicated by its abnormal ratio. It is extremely enriched in Ba. Both the G1—G3 and G2—G3 mixtures show the presence of the G3 microcline by being high in Ba. It is considered that the G3 microcline is not genetically related to the major pegmatite crystallisation. High Ba contents are typically associated with the high temperature, least fractionated, K-feldspars in normal rocks. However, also adularia of low temperature veins are typically high in Ba, and the Ba- feldspar, Celsian, is a product of low temperatures of formation. The amazonite (G2) and the G1—G2 transition feldspars have rather uniform Ba/Sr ratios. It was suggested that the amazonite formed through reactions between the G1 microcline and the "pegmatite rest liquid" from which cleavelandite crystallised. Fig.

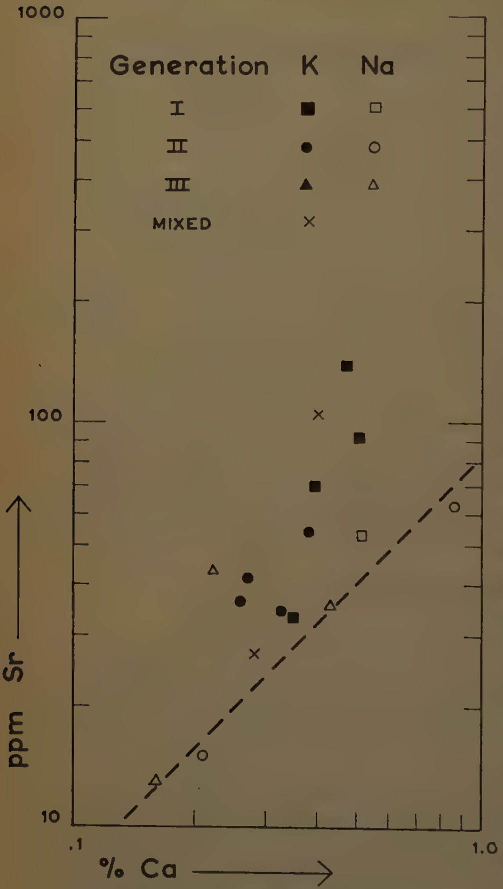

Fig. 8. Ca/Sr relationship. A close association is apparent in the plagioclase feldspars, but not in the K- feldspars.

7 gives some support for this assumption in that the amazonites and the amazonite-G1 transition series gradually changes towards typical plagioclase ratios by increasing "amazonitization".

As can be seen from Fig. 7 barium is a more sensitive indicator of the different generations than is strontium. The first generation K- feldspars contain 100—250 ppm Ba, the second generation less than 60 ppm and the third over 3000 ppm. These variations are not reflected by the plagioclase, probably for structural reasons. The cleavelandites are higher in Ba than the albites, and contain about the same concentrations as the coexisting amazonite.

The Sr/Ca ratios are not useful in distinguishing the various generations. The interesting feature here is the Ca–Sr coherence shown by the plagioclase feldspars (Fig. 8) and the relative enrichment in Sr relative to Ca displayed by the K- feldspars.

The green colour of amazonite.

Goldschmidt et al (1933), Tolmachev and Filipov (1935) and Ahrens (1945, p. 229) noted the large amounts of Rb in amazonites. Kapustin (1939) correlated the green colouration with the amount of Rb; this was also the opinion of Zavaritshy (1943). Borovik–Romanoya and Kalita (1958) state that Rb is not responsible for the green colour. Goldschmidt (1954) noted that since both Rb-poor amazonites and Rb-rich red microclines are not uncommon, Rb could not be responsible, but thought that perhaps Tl, normally a close associate of Rb might be the cause. He found no trace of Cr, Ni or Cu in amazonites. He did not think that the Pb present would affect the colour. ZIRHOV (personal communication with Professor L. H. AHRENS) considers that the substitution of ($Pb^{2+}Al^{3+}$) for ($K^{+}Si^{4+}$) takes place in microclines, but that in amazonites Pb^{2+} substitutes for $2K^{+}$, with a defect lattice resulting, which is responsible for the change in colour. ELISEEV (1949) and BASSETT (1956) attribute the green colour to ferrous iron.

A good opportunity exists in sample 11 (see Plate 2, Fig. 1). to examine the ideas which have been proposed to account for the green colour of amazonite, since in this sample a transition between green amazonite and pink microcline takes place.

Table 4. Comparison of the amounts of Fe, Cr, Mn, and Cu in pink microcline and green amazonite Plate 2, (Fig. 1).

Sample No.	Fe ppm	Cr ppm	Mn ppm	Cu ppm
11.7 green	290	0.11	10	3.8
11.8 pink	480	0.26	14	1.0
11.9 pink	470	0.23	15	1.2

The following elements were not detected in any of the samples (approximate detection limits are given in brackets).
F (100), Sn (50), Be (50), Co (5), Ni (1), V (1).

On a series of drilled samples 1 cm apart (11.1 to 11.6) we have determined Li, Na, K, Rb, Cs, Pb, Tl, Ca, Sr and Ba. Samples 11.7 to 11.9 were taken with extreme precautions to avoid metallic contamination and were used for the determination of Cu, Fe, Mn and Cr. Figures for these elements are given in Table 4. V, Co and Ni were not detected in these samples. An examination of the spectra of these three samples from 2470 to 9600 Å revealed no differences other than those tabulated. The only significant differences are that the amazonite contains rather more Ca and much less Sr and Ba than the microcline. These elements are rather critical indicators of fractionation (TAYLOR and HEIER, 1960; HEIER and TAYLOR, 1959 b). However, this difference is not more than that observed rather commonly in pegmatite feldspars of the same colour (see for example, data given by TAYLOR and HEIER, 1960, and HEIER and TAYLOR, 1959 b).

In Plate 2, Fig. 2 the alkali metal spectra are shown for 11.7, (green), 11.8 and 11.9 (red). These spectra show the uniform amounts of Rb and Cs. In Plate 2, Fig. 3 the spectra of the standard granite G–1 with 700 ppm F, the standard diabase W–1 with 200 ppm F (AHRENS and FLEISCHER, 1960), and samples 11.7 (green) and 11.8 (red) are shown. The CaF bandhead at 5291 Å may be seen clearly in G–1, less distinctly in W–1, and is absent in both the amazonite and the microcline.

Amazonites are commonly higher in Rb, Cs, Pb, Tl and lower in Ca, Sr and Ba than normal pegmatite feldspars, and are clearly products of an extreme fractionation process. We are lead to the conclusion that the cause of the green colouration is not to be found in a significant difference in composition from the microcline from the elements: Li, Na, K, Rb, Cs, Pb, Tl, Ca, Sr, Ba, Ga, Al, Si, Cu, Fe, Mn, Cr, V, Co, Ni, Sn, Be, and F.

It seems that the change in colour must be caused by physical differences, such as lattice defect or strain, rather than by chemical differences.

Acknowledgements.

We are grateful to Miss Maureen Sachs for assistance with sample preparation and the spectrographic determinations; to Mr. B. Bruun and Miss K. Haugen for the Na and K determinations; to Professor I. Oftedal for some preliminary spectrographic determinations; to Professors L. H. Ahrens and T. F. W. Barth, and Dr. H. Neumann for reading the manuscript and for constructive suggestions.

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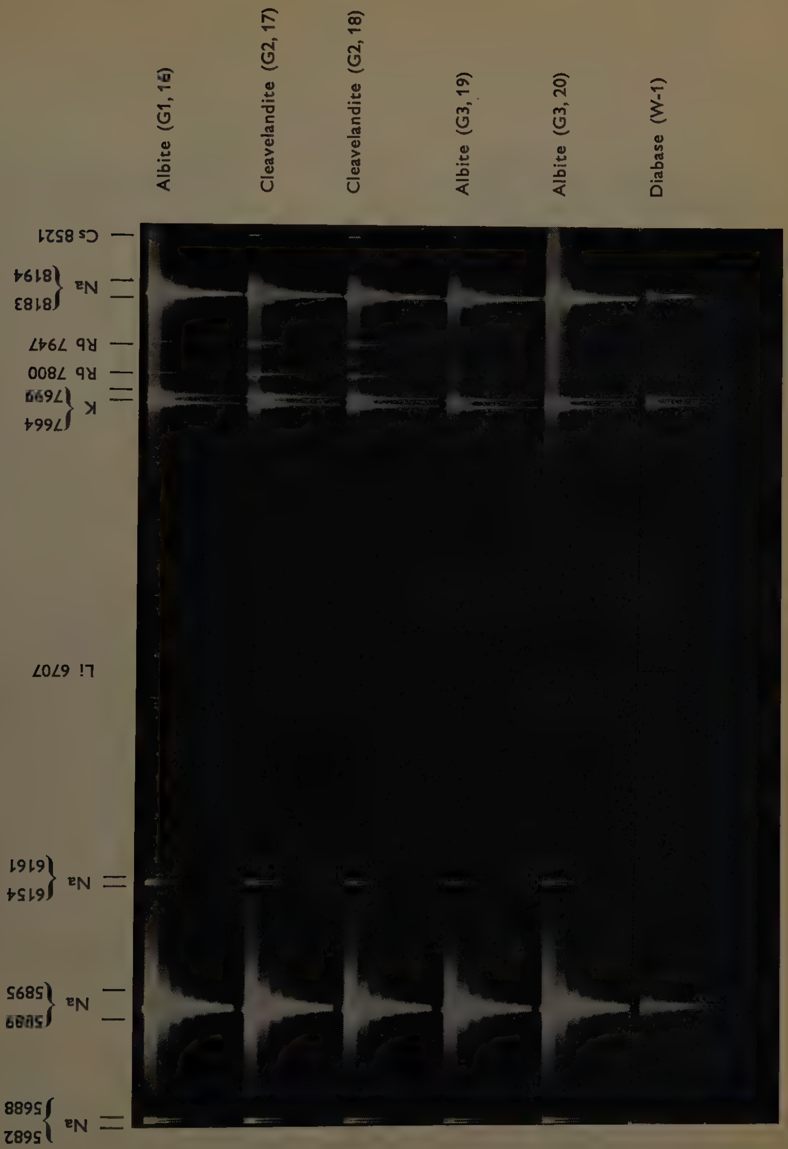
Manuscript received January 13, 1960.
Printed June 1960.

PLATE I.



Alkali element spectra of plagioclase feldspars. Samples 16, 19 and 20 have normal K/Rb ratios and no Cs. The spectrum of the standard diabase, W–1 (Ahrens and Fleischer, 1960) is shown for comparison. It can be seen to have a similar K/Rb ratio to samples 16, 19 and 20. The cleavelandite samples (17, 18) are enriched in Rb relative to K, and have detectable Cs.

PLATE II.

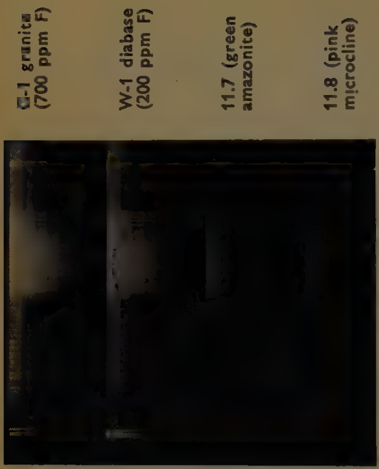


Fig. 3

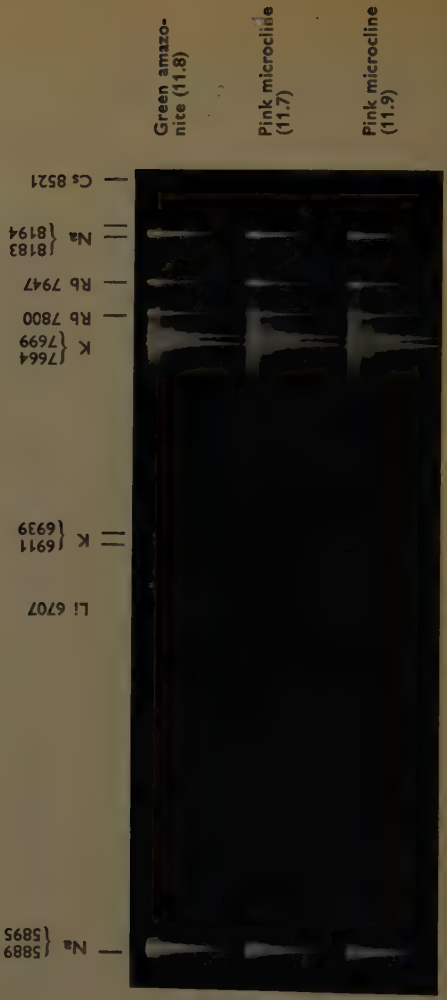


Fig. 2

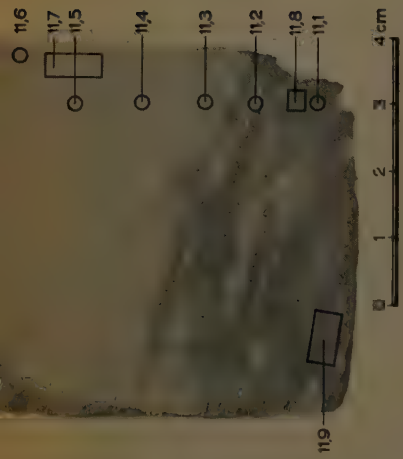


Fig. 1

Fig. 1. Transition between green amazonite (light) and pink microcline (dark). The position of the samples are indicated.

Fig. 2. Alkali metal spectra of green amazonite (sample 11.7) and adjacent pink microcline (11.8 and 11.9). The spectra are very similar.

Fig. 3. The CaF bandhead at 5291 Å can be seen easily in the standard granite G–1 (700 ppm F) and less clearly in the standard diabase W–1 (200 ppm F) (Ahrens and Fleischer, 1960). It is not present in either the green amazonite (11.7) or in the pink microcline (11.8). The other band spectra are due to CaO ($CaCO_3$ was added to all samples).

CONTRIBUTIONS TO THE MINERALOGY OF NORWAY

No. 6. On the chemical composition of blomstrandine and euxenite.

By

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Blindern, Norway.)

Abstract: Complete analyses of two samples of blomstrandine and two samples of euxenite were carried out by chemical methods and by emission and fluorescent x-ray spectroscopy. Pure mineral samples were prepared by repeated treatment with heavy liquids and by magnetic separation. The major constituents were determined by chemical methods; niobium, tantalum, and titanium being separated and determined by precipitation with the organic reagent N-benzoyl-N-phenylhydroxylamine. Minor and trace elements were determined by emission spectroscopy and rare earths by fluorescent x-ray spectroscopy.

Introduction.

The analysis of minerals and ores containing niobium, tantalum, and titanium is regarded as one of the more difficult types of analysis. The analytical separation of these elements is particularly difficult, and earlier separation methods have in many cases proved to be inadequate.

In a previous paper (1), the authors described a procedure for separation and gravimetric determination of niobium, tantalum, and titanium by precipitation with N-benzoyl-N-phenylhydroxylamine. Procedure was applied, and satisfactory results were obtained in the analysis of solutions containing known amounts of niobium, tantalum, and titanium.

It was also found of interest to test the applicability of the reagent and the procedure in the analysis of complex niobium-, tantalum- and titanium-bearing substances, and for this purpose the minerals blomstrandine and euxenite were selected. These minerals, classified as titanoniobates, contain as essential constituents niobium, titanium. and tantalum, as well as rare (usually yttria) earths. In addition a series of minor and trace constituents are present.

New data on the chemical composition of blomstrandine and euxenite obtained by improved analytical methods were believed to be of interest also to the mineralogists, and it was therefore decided to carry out complete analysis of representative samples of the minerals.

Selection and origin of samples.

From the collection at the Mineralogical Museum, University of Oslo the following samples were selected for analysis:

Blomstrandine from Kåbuland, Iveland; blomstrandine from Rasvåg, Hitterøy; euxenite from Kalstadgangen, Kragerø; euxenite from Eitland, Farsund.

Mineral separation.

The samples contained blomstrandine and euxenite intimately mixed with other minerals, and extensive separations were necessary to obtain uncontaminated materials.

Each sample was initially divided into two portions, of which one was taken for analysis, while the other was reserved for microscopical examination and reference.

The samples selected for chemical analysis were broken into small pieces and crushed in a steel mortar to pass a 90 mesh sieve. The finest fraction (including dust) was removed by suspension in water. A hand magnet was applied to remove fragments of the mortar and the main part of strongly magnetic minerals. Blomstrandine and euxenite were then separated from the other minerals by repeated treatment with heavy liquids (tetrabrommethane; density 3.0 and thallium malonate-thallium formate; density 4.0) and by use of Franz isodynamic, magnetic separator. The separations were followed by x-ray and microscopical examination, and in the final products the only mineral contaminations detected by these methods were: Xenotime in the sample of blomstrandine from Kåbuland, and xenotime and anatase in the sample of blomstrandine from Rasvåg. The amounts of these minerals are negligible as seen for example by the determination of phosphorus, see Table 1.

Qualitative analysis.

The 4 mineral samples were analysed by emission and fluorescent x-ray spectroscopy, and the following elements were detected: Nb, Ta, Ti, U, Th, Y, Yb, Er, Dy, Gd, Lu, Tm, Pb, Sn, Fe, Al, Mg, Ca, Ba, Sr, Cr, Mn, Si, Zr, Sc, traces of Co, Cu, Ni, K and Na. Nonmetallic constituents present were phosphorus and water.

The following elements were sought for, but could *not* be detected by the methods employed:

La, Ce, Pr, Nd, Sm, Eu, Tb, Ho, Sb, Be, Bi, Ge, Au, Hf, W, In, Mo, platinum metals, Ag, Tl and V.

Small amounts of La, Ce and Eu were later detected in all rare earth fractions by emission spectroscopy, see Table 1.

Quantitative analysis.

The complete analysis of the minerals were accomplished by chemical methods and by emission and fluorescent x-ray spectroscopy. The main constituents were determined chemically, trace elements by emission spectroscopy, and the rare earths by fluorescent x-ray spectroscopy.

In Table 1 the results are given for the four minerals analyzed.

The purity of some of the weighed oxides of niobium, tantalum and titanium was controlled by emission spectroscopy. The weighed oxides of niobium contained about 1 % of tantalum pentoxide, while their content of titanium dioxide varied from 0.1 % up to about 1%. The oxides of tantalum contained some per cent of niobium pentoxide and from about 0.1 % up to about 1 % of titanium dioxide. Finally, the oxides of titanium contained about 0.01 % of the pentoxide of niobium and about 0.01 % of the pentoxide of tantalum.

Table 1. Analytical Data (in per cent) of Blomstrandine and Euxenite.

Constituent	Method of determination	Blomstrandine		Euxenite	
		Kåbuland	Rasvåg	Eitland	Kalstadgangen
Nb_2O_5	Chem.	17.72	14.26	23.19	23.49
Ta_2O_5	»	4.29	2.59	0.49	2.55
TiO_2	»	31.71	35.20	25.45	25.64
SiO_2	»	0.28	0.24	0.51	0.47
ZrO_2	Em. spectr.	< 0.01[2]	< 0.01[2]	< 0.01[2]	< 0.01[2]
SnO_2	Chem.	0.05[3]	0.07[3]	0.20[3]	0.12[3]
UO_2	»	4.32	1.27	7.80	7.95
UO_3	»	0.08	2.40	4.32	nil
ThO_2	»	5.80	5.78	2.85	2.40
Σ rare earths[1]	»	24.90	27.71	22.70	25.77
Sc_2O_3	Em. spectr.	< 0.005	< 0.005	0.06	0.03
PbO	Chem.	0.05	0.03	0.36	0.12
Al_2O_3	Em. spectr.	0.60	0.60	0.07	0.07
FeO	Chem.	0.34	0.53	0.83	0.40
Fe_2O_3	»	3.33	3.96	3.89	4.66
MnO	»	0.20	0.21	0.46	0.18
MgO	Em. spectr.	0.06	0.10	0.05	0.08
CaO	»	1.7	1.0	2.4	2.8
BaO	»	< 0.001[4]	< 0.001[4]	< 0.001[4]	< 0.001[4]
SrO	»	< 0.001	< 0.001	< 0.001	< 0.001
Cr_2O_3	»	< 0.001	< 0.001	< 0.001	< 0.001
CoO	»	< 0.001	< 0.001	< 0.001	< 0.001
NiO	»	< 0.001	< 0.001	< 0.001	< 0.001
CuO	»	< 0.001	< 0.001	< 0.001	< 0.001
K_2O	»	Not detected < 0.1[2]	Not detected < 0.1[9]	Not detected < 0.1[2]	Not detected < 0.1[2]
Na_2O	»				
P_2O_5	Chem.	0.11	0.04	n. d.[5]	n. d.[5]
H_2O +110° C	»	3.99	3.53	3,63	3.26
Total		99.53	99.52	99.26	99 .99
Density	Pycnometr.	4.838	4.786	4.826	4.797

[2] Not included in total.

[3] The stannic oxide is contaminated with barium.

[4] The actual content of barium is probably higher.

[5] n. d. = not determined. (The microscopical examination of these samples showed that Xenotime was absent.)

Table 1, (Cont.)

Constituent	Method of determination	Blomstrandine		Euxenite	
		Kåbuland	Rasvåg	Eitland	Kalstadgangen
[1]Separate rare earths:	Fluorescent X-ray spectr.	(The content of the separate rare earths are given in per cent of the rare earth fractions)			
Pr_2O_3	»	not detected	0.30	not detected	not detected
Nd_2O_3	»	3.80	3.65	3.00	2.30
Sm_2O_3	»	5.40	3.65	2.45	3.80
Gd_2O_3	»	6.80	4.60	3.90	5.80
Tb_2O_3	»	1.50	1.25	1.05	1.60
Dy_2O_3	»	8.65	9.10	8.00	10.80
Ho_2O_3	»	1.65	1.90	2.10	2.25
Er_2O_3	»	6.20	7.60	9.30	8.25
Tm_2O_3	»	not detected[6]	not detected[6]	not detected[6]	not detected[6]
Yb_2O_3	»	9.30	12.00	15.00	14.50
Lu_2O_3	»	0.95	1.30	1.90	1.40
Y_2O_3	»	51.00	55.75	52.00	51.00
La_2O_3	»	< 1.0	< 1.0	< 1.0	< 1.0
Ce_2O_3	»	< 1.0	< 1.0	< 1.0	< 1.0
Eu_2O_3	Em. spectr.	$\leqq 0.1$	$\leqq 0.1$	$\leqq 0.1$	$\leqq 0.1$

[6] Thulium was detected by emission spectroscopy.

Analytical methods.

The methods applied in the chemical analyses will be outlined shortly.

The mineral samples were pulverized in an agate mortar, dried at 105°—110° C and stored in a desiccator. About 0.5 g were weighed out and fused with potassium pyrosulphate. The melt was dissolved in a mixture of sulphuric and tartaric acid (30—40 ml of 25 % tartaric acid solution containing 2 ml of concentrated sulphuric acid). Without filtering the solution, hydrogen sulphide was introduced. The precipitated sulphides together with hydrated silica and small amounts of titanium and earth acids were collected on a medium-textured filter paper, (the filtrate being reserved for later determinations), and the precipitate was dried, charred and ignited at about 600° C. The residue was decomposed by fusion with a small amount of potassium pyrosulphate and the melt was dissolved as described above. The undissolved material was filtered, ignited at low temperature in a previously weighed platinum crucible and weighed as the sum of lead sulphate and the dioxides of tin and silicon. The filtrate was added to the main filtrate. Silica was determined in the usual way by evaporation with hydrofluoric and sulphuric acid. Lead was then dissolved by treating the residue with ammonium acetate solution. Hydrous stannic oxide was filtered off and determined gravimetrically as stannic oxide. Lead was finally precipitated and weighed as lead chromate. To the combined filtrates were added 2.5 g of ethylenediamine tetra-acetic acid, disodium salt, and sulphuric acid until the solution was about 0.2 N with regard to this acid. Niobium, tantalum and titanium were then precipitated (The addition of macerated filter paper before precipitation is recommended.) with a 10 % solution in ethanol of N-benzoyl-N-phenylhydroxylamine, the reagent being added in an amount 8—10 times the amount of metals present. The beaker with the precipitate was left on the boiling water bath for 45—60 min. The precipitate was collected on a loose-textured filter paper and ignited at about 600° C. The oxides were decomposed again with potassium pyrosulphate, the melt was dissolved as before in a mixture of sulphuric and tartaric acid, and niobium, tantalum and titanium were reprecipitated with N-benzoyl-N-phenylhydroxylamine under the conditions given above. The precipitate was treated as described above and finally ignited at about 900° C.

Niobium, tantalum and titanium were then separated and determined with N-benzoyl-N-phenylhydroxylamine according to the detailed procedure given by the authors in a previous publication[1]. The filtrate after the final precipitation of titanium may contain small amounts of coprecipitated constituents, and should therefore be reserved for the determination of the remaining elements.

The combined filtrates after the precipitation of niobium, tantalum and titanium were evaporated on the hot plate, and organic matter was destructed with fuming nitric acid. The further determinations were carried out according to the conventional procedures given in the textbooks by SCHOELLER and POWELL(2) and by HILLEBRAND, LUNDELL, BRIGHT and HOFFMANN(3). A double group precipitation with ammonia solution separated iron, aluminium, thorium, uranium, rare earths etc. from alkaline metals, earth alkaline metals and manganese which were determined separately. The hydroxides were dissolved in hydrochloric acid. Thorium and rare earths were precipitated together with oxalic acid, and thorium was separated from the rare earths by a double precipitation with hexamethylenetetramine. The filtrate after the precipitation with oxalic acid was treated with fuming nitric acid to destruct organic matter. Iron was precipitated with cupferron and determined gravimetrically as ferric oxide. Uranium (VI) was reduced to uranium (IV), precipitated with cupferron and finally weighed as U_3O_8. The following constituents were determined separately by conventional methods: quadrivalent uranium, manganese, phosphorus, ferrous iron and water (H_2O^+). The density of the minerals was determined pycnometrically.

Advantages of decomposition by HF. In the present investigation the minerals were decomposed by fusion with potassium pyrosulphate. By this procedure and by the subsequent additions of sulphuric acid considerable amounts of sulphates were introduced, and the precipitates of niobium, tantalum and titanium were contaminated with sulphates which were difficult to remove completely by washing.

In order to avoid the high concentrations of sulphate, hydrofluoric acid was tried as decomposing agent for the mineral samples and also for the oxides of the earth acids and titanium. This method of attack was found to offer advantages. The coprecipitation of sulphates was considerably lowered, and in addition a quantitative separation of insoluble rare earth and alkaline earth fluorides from the soluble fluorides of earth acids and titanium was obtained. At the same time quadrivalent uranium was separated from sexivalent uranium. It was also possible to replace the intial double precipitation of niobium, tantalum and titanium (in the presence of ethylenediamine tetra-acetic acid, disodium salt and tartaric acid) by a single precipitation.

The analytical data obtained with the two decomposition methods compared favourably, but the method of attack by hydrofluoric acid seems to offer advantages in the analysis of minerals soluble in this acid. The application of hydrofluoric acid as decomposing agent necessitates a separate determination of silica. Silica, tin and lead are conveniently determined by a separate decomposition with potassium pyrosulphate.

Acknowledgements.

The authors are indebted to Professor T. F. W. Barth and Dr. H. Neumann for their help in selecting the mineral samples and for the facilities placed at our disposal for the mineral separations. The authors also wish to express their appreciation to the Royal Norwegian Council for Scientific and Industrial Research for partial support of the work and to Statens Råstofflaboratorium, Trondheim for the emission and fluorescent x-ray spectroscopical determinations.

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Manuscript received January 27, 1960.
Printed June 1960

NORSK GEOLOGISK FORENING

Møte nr. 385, Julemøte, torsdag 10. desember 1959

i Drammensveien 78, Oslo.

Til stede 30 medlemmer, 20 gjester.
Referat fra møte nr. 384 ble opplest og godkjent.
Innvalg av følgende nye medlemmer ble godkjent:

448. Mr. S. B. Smithson, Mineralogisk- Geologisk Museum, Sarsgt. 1, Oslo. Foreslått av Knut S. Heier og Henrich Neumann.
449. Ingeniør, cand. mag. Josef Lien, Bjørnsonsgt. 16, Bergen. Foreslått av Ivar Hernes og Inge Bryhni.
450. cand. mag. Kjell Tjølsen, Geologisk Institutt, Bergen. Foreslått av Ivar Hernes og Inge Bryhni.
451. cand. mag. Johan Naterstad, Geologisk Institutt, Bergen. Foreslått av Ivar Hernes og Inge Bryhni.
452. Stud. real. Tore Torske, Geologisk Institutt, Bergen. Foreslått av Ivar Hernes og Inge Bryhni.

Aftenens foredragsholder var Dr. *Tore Gjelsvik* som fortalte om «Ekspedisjonen til edelstensfelter og jadegruver i Burmas jungel».

Generalforsamling torsdag 11. februar 1960

i Drammensveien 78, Oslo.

Til stede 32 medlemmer.
Årsmelding og regnskap for 1959 ble godkjent.
Revisorene hadde gjort følgende anmerkning til regnskapet:

«Vi finner det uheldig at såvidt store beløp av Livsvarige medlemmers fond og Berg- og steinindustriens fond står som bankinnskudd, og henstiller til styret å ta spørsmålet opp med de respektive fondstyrer og med revisorene».

Generalforsamlingen sluttet seg til denne henstillingen.

Reuschmedaljekomitéen for 1959 hadde ikke funnet å kunne fremme noe forslag for tildeling av Reuschmedalien for 1959.

Valg.

Formann: *H. Bjørlykke.*
Viseformann: *T. Strand.*
Sekretær: *T. Siggerud.*
Redaktør: *N.-H. Kolderup.*
Styremedlemmer: *G. Aasgaard, K. Egede Larssen* og formennene i Bergens og Trondheims geologiske klubber, *H. Holtedahl* og *R. Selmer-Olsen.*
Revisorer: *G. Henningsmoen, J. A. Dons* med *F. Hagemann* og *K. Bryhn* som varamenn.
Redaksjonskomité: *T. Barth, J. Bugge, A. Heintz, O. Holtedahl, T. Strand.*
Reuschmedaljekomité: *H. Bjørlykke, G. Henningsmoen, P. Holmsen,*
Komitéen for Berg og steinindustriens fond: *A. Eriksen, P. Holmsen, T. Gjelsvik.*

Som nytt medlem av komitéen for Hans og Helga Reusch's legat ble valgt *H. Bjørlykke* istedenfor *S. Føyn* som hadde bedt om å få uttre. Komitéen har nå følgende sammensetning:

K. Strøm (ex officio), *L. Størmer* (ex officio), *I. Oftedal, N.-H. Kolderup, H. Bjørlykke. A. Granli* ble gjenvalgt som foreningens forretningsfører.

Under posten eventuelt anmodet Dons styret om å overveie mulighetene for forandring av valglovene slik at skriftlig valg kan unngåes når bare en kandidat er nominert.

Årsmelding for 1959.

Siden forrige generalforsamling er følgende medlemmer avgått ved døden:

Bergingeniør Henning Marstrander,
Dr. Einar Jensen,
Cand. mag. E. M. Nørregaard,
Laboratorieingeniør Kr. Stenvik.
Konservator Astrid Monsen.

2 medlemmer er utmeldt av foreningen.
I samme tidsrom er det innvalgt 19 nye medlemmer.
Foreningen har nå 266 medlemmer, derav:

2 korresponderende,
131 livsvarige,
133 årsbetalende.

Det er siste år avholdt 6 ordinære møter med et samlet fremmøte av 178 medlemmer og 77 gjester.

Det er også avholdt en geologisk ekskursjon hvor 21 medlemmer og 14 gjester deltok.

Av Norsk Geologisk Tidsskrift er utkommet Bd. 39, hefte 1—4.

Styret har i 1959 bestått av:

T. Strand, formann.
N. Spjeldnes, viseformann.
K. S. Heier, sekretær.
N.-H. Kolderup, redaktør.
Kari Egede Larssen, styremedlem.
A. Eriksen, styremedlem.

Formennene i Bergens og Trondheims geologiske klubber, A. Granli har virket som foreningens forretningsfører.

Utdrag av regnskap for det ordinære budsjett for 1959.

Inntekt

Beholdning, overført fra 1958: I kasse	....kr. 504,13	
I bank	.... » 2 078,48	kr. 2 582,61
Innbetalt kontingent		» 2 235,00
Tilskudd fra Staten		» 1 200,00
Tilskudd fra Norges Almenvitenskapelige forskn.råd		» 15 000,00
Abonn. og salg av tidsskrifter		» 3 323,20
Renter av bankinnskudd		» 61,95
» fra livsvarige medlemmers fond		» 910,96
» fra Berg- og Steinindustriens fond		» 600,26
		kr. 25 913,98

Utgift

Tidsskriftet:		
Trykking, Bind 38, hefte 3—4 (Rest)		kr. 2 018,00
Trykking, Bind 39, hefte 1—3		» 15 346,00
Klisjéer, Bind 39, hefte 1—3		» 3 215,00
Korrektur og tegnearbeide		» 993,65
Ekspedisjon av tidsskriftet		» 997,85
Arbeidshjelp, porto og skrivesaker		» 610,25
Møter og ekskursjoner		» 499,76
Representasjoner, anskaffelser og Reuschmedaljen		» 116,76
Beholdning, overført til 1960: I kasse	.... kr. 125,73	
I bank	.... » 1 990,98	» 2 116,71
		kr. 25 913,98

Livsvarige medlemmers fond 1959:

		Inntekt	Utgift
1/1—59. Fondets kapital ...	kr. 21 260,00		
Innbet. kont. i 1959	» 1 700,00		
	kr. 22 960,00		
Herav i statsobl. og aksjebrev	kr. 14 100,00		
I bank	» 8 860,00		
31/12—1959. Urørlig kapital	kr. 22 960,00		
Renter av verdipapirer for 1959		kr. 735,50	
Renter av bankinnskudd for 1959		» 198,46	
Forvaltning av verdipapirer			kr. 23,00
Overført til ordinære budsjett			» 910,96
		kr. 933,96	kr. 933,96

Berg- og steinindustriens gavefond:

Fondets kapital ...	kr. 20 000,00		
Renter av bankinnskudd		kr. 600,26	
Overført til ord.budsjett			kr. 600,26
		kr. 600,26	kr. 600,26

Regnskapet revidert av Tore Gjelsvik og H. Genningsmoen, 18/1—1960

Møte nr. 386, torsdag 11. februar 1960.

i Drammensveien 78, Oslo.

Til stede 32 medlemmer og 6 gjester.

Forsamlingen mintes konservator Astrid Monsen som var avgått ved døden siden forrige møte.

Som nye medlemmer ble innvalgt:

453. Cand real. Arne W. Grønhaug, Arupsgt. 10, Oslo. Foreslått av S. Bergstøl og K. S. Heier.
454. Bergingeniør Mikal Sletthaug, Seterveien 14, Oslo. Foreslått av H. Bjørlykke og Johs. Færden.
455. Lektor Bjørge Løkås, Harry Borthens vei 8, Østmarkneset, Trondheim. Foreslått av R. Selmer-Olsen og H. Carstens.

Aftenens foredragsholder var Dr. *G. Holmsen:*

«K. O. Bjørlykke 1860—1946, minnetale ved hans 100 årsdag».

Etter foredraget rettet Dr. H. Bjørlykke på familiens vegne en takk til foreningens styre og til foredragsholderen.

Møte nr. 387 torsdag 3. mars 1960 kl. 19

i Drammensveien 78, Oslo.

Tilstede 41 medlemmer og 25 gjester.
Viseformannen ledet møtet.

Referat fra generalforsamlingen og fra møte 386 ble lest opp og godkjent med en bemerkning om at antall tilstedeværende på generalforsamlingen manglet. Navn på styremedlemmer som representerer Bergen og Trondheim geologiske klubber var ikke kommet inn.

Som nye medlemmer ble innvalgt:

456. Professor E. S. W. Simpson, Department of Geology, University of Cape Town, Rondebosch, Syd-Afrika. Foreslått av Barth og Neumann.
457. Cand.mag. Haldis Bollingberg, Institutt for geologi, Universitetet Blindern.
458. Cand.mag. Boye Flood. Institutt for geologi, Universitetet Blindern. Begge foreslått av Skålvoll og Hysingjord.

Deretter holdt dr. philos. *Just Gjessing* foredrag om: «Terrengformer dannet under isavsmeltningstiden i Østlandets nordlige dalområder.»

I ordskiftet etter foredraget deltok O. Liestøl, G. Holmsen, P. Holmsen, O. Holtedahl, T. Gjelsvik, B. Andersen og foredragsholderen.

Autorreferat av dr. Gunnar Holmsens diskusjonsinnlegg etter dr. Just Gjessings foredrag i Norsk Geologisk Forening 3. mars 1960.

Jeg har lest og satt meg inn i Just Gjessings fremstilling i hans doktoravhandling «Isavsmeltningstidens Drenering».

De store trekk i innlandsisens smeltningsforløp i bresjøregionen nordvest for isskillet kjenner vi ved hjelp av sporene etter brerandlinjer og den kronologiske rekkefølge av utløpsoser for det oppdemte vann. Gjessings doktoravhandling tilstreber å utvide vår erkjennelse herav ved å gi detaljerte beskrivelser, karter og kartskisser, særlig fra Nordre Atnedalen.

Jeg har festet meg mindre ved Gjessings betraktninger fra Atnedalen enn ved hans mangel på fremstilling av de bredemte sjøers vitnesbyrd i Nordre Østerdalen, og jeg konstaterer, at diskusjonen om disse sjøers strandmerker, som for 50 år siden reiste så høye bølger her i Geologisk Forening, ennu ikke har lagt seg til ro.

Når jeg velger å la mitt innlegg i diskusjonen omfatte denne mangel, er det fordi Gjessings resonnement over akkumulasjonenes oppståen på det nærmeste bortser fra sedimentasjonen i sjøene. Jeg mener, at de bredemte sjøers område med sine fri vannflater fremdeles er det klassiske sted for studiet av de under deglasiasjonen fremståtte terrengformer nord for isskillet, og en utelukkelse av dette viktige morfologiske ledd er en hasardiøs mangel.

Gjessing nevner innledningsvis, at jeg i «Brædæmte Sjøer», som utkom for 45 år siden fremstilte Glåmsjøene som sammenhengende, åpne vannflater. Det er riktig det, at jeg ikke beskjeftiget meg noe videre med tanken på den gjenliggende dødis i de oppstuvete bresjøer. Men tanken herpå var meg ikke fremmed, som det eksempelvis fremgår av min ytring på s. 185 i boken, hvor det tydelig og greit står, at der kunne komme en tid da breen ikke beveget seg. Sådanne brelevninger kalte jeg allerede dengang for «dødis», en betegnelse, som Reusch tidligere hadde lansert.

Gjessing innrømmer dog, at jeg senere har modifisert min oppfatning av de store, åpne sjøers vannflate, men hvori dette består er ikke noe sted meddelt i hans avhandling.

For Gjessing er de bredemte sjøers vannflater et «grunnvannspeil», — en nedslående forveksling, som vitner om kvartærgeologiens svake stilling i vårt land, og hvis konsekvens er, at det ennu ikke ansees fastslått, at der har ligget flere kommuniserende, over store områder åpne vannflater i Nordre Østerdalen med erosjonsstrandlinjer i lisidenes bregrus.

Gjessing har i sin doktoravhandling slått en strek over det solide materiale av nivellerte strandlinjehøyder som er å finne i «Brædæmte Sjøer» og «Rendalens Bræsjø», og hva verre er, opponentene under den offisielle doktordisputas hoppet bukk over de vitnesbyrd de åpne vannflaters eksistens gir.

Strandlinjene i Glåmdalen, Andr. M. Hansens «seter», er knyttet til 2 meget vel avgrensete høyder. Passhøydene for utløpene av Øvre og Nedre Glåmsjø slutter seg med full overensstemmelse til strandlinjene, den isostatiske hevning tatt i betraktning. Nedre Glåmsjøs strandlinjer stiger henimot isskillet, således at strandlinjene i Rendalen og Brydalen ligger nu på 671 m o. h., vannskillet i Rugldalen på 665, og strandlinjene ved Lien, Alvdal, på 653 m o. h. Dette er nivellerte høyder, og middelverdien for hver enkelt strandlinje har små avvikelser fra de i marken målte punkter.

Avstanden mellom de nivellerte strandlinjer i Fonnåsfjellet ved Unset og ved Lien er 32 km. Retningen mellom dem er nordvest—sydøst, og høydeforskjellen 18 m. Dette gir en gradient i nordvestlig retning for Nedre Glåmsjø på litt over 1/2 m på kilometeren. —

Avstanden mellom strandlinjene på Øvre Glåmsjøs nivå i Tynset ved Holan og Vangen til vannskillet Tunna—Orkla på høyden 700 m er 30 km og høydeforskjellen 16 m, d.v.s. en gradient i nordvestlig retning av samme størrelse.

Dette har Gjessing oversett når han i innledningen til sin avhandling skriver, at landhevningens størrelse eller dens skråhet ikke kan bestemmes for de behandlete områder.

Dalene nord for isskillet ble ikke isfri samtidig som deres uttapning fant sted. Der er tegn til at dødiser ble liggende igjen i dalbunnene, og at vannløpene i denne periode har frembrakt karakteristiske akkumulasjoner, som er blitt bygget opp til dødisens kanter, og som de har støttet seg til. Min oppfatning er, at også mange eskere (således Hådalens, Værådalens, Tufsingdalens og mange andre) stammer fra tiden etter tappingen av bresjøene.

Oslo 5. mars 1960.

Gunnar Holmsen

Trondheims Geologiske Klubb

Årsmelding for 1959.

Møte nr. 15. 4. februar.

Amanuensis R. Selmer-Olsen: «Sedimentpetrografiske undersøkelser på kartbladet Kragerø».

Møte nr. 16. 6. april.

Professor Anders Kvale: «Strukturundersøkelser i Gotthardområdet».

Møte nr. 17. 4. mai.

Konservator J. A. Dons: «Telemarkformasjonens suprakrustaler; granitt og fossiler. Nytt fra 4. kartblad».

Møte nr. 18. 29. september.

Professor Chr. Oftedahl: «Vulkanittene i fjellkjeden».

Møte nr. 19. 3. november.

Dr. H. P. Geis: «Strukturelle iakttagelser ved noen norske kisforekomster».

Møte nr. 20. 2. desember.

Geolog John Fortesque: «Geochemistry in prospecting».

Styret i 1959 var:

Formann: R. Selmer-Olsen.
Sekretær: H. Carstens.
Styremedlem: J. Bugge.

APPARENT AGES OF NORWEGIAN MINERALS AND ROCKS

By

HENRICH NEUMANN

A great many age determinations of Norwegian minerals and rocks have been done during a long period of time, by many investigators applying a number of different methods. Some of the results are easily overlooked by geologists as they are published in journals which are not too commonly read, and some have never been published earlier but are given as personal communications. The author would like to express his gratitude to the persons concerned for permission to use data which is not already published elsewhere.

The intention of this paper is first to collect the existing data and make it more easily available to those interested, and discussions of the reported ages have been reduced to a minimum.

Also, for ease of reference, age data have been listed without further comments as they were given by the investigators concerned at the time of publication or personal communication. The figures have not been recalculated, i. e. with respect to possible later corrections of radioactive constants, to make them mutually comparable. Naturally, such recalculations will have to be performed before a more thorough and detailed discussion can be undertaken than that offered in this preliminary paper.

Some of the apparent ages given in table 1 are now of historical interest only, and some of them should for different reasons be disregarded. U/Pb and Th/Pb ages or a combination of them, without isotope determinations may in some cases be remarkably correct, in other cases they are very misleading, and should therefore be discarded because of their unreliability. Lead-alpha ages of zircons will give a first approximation only, and are too crude to merit any further discussion. The same applies to some extent to K/Ar ages of feldspars, as the causes of a later leakage of already built up Ar in this mineral are not at present sufficiently well understood to permit any safe conclusions concerning the history of formation of the feldspars in question on the basis of their apparent K/Ar ages.

The Re/Os dating of molybdenites (and other minerals with a sufficiently high content of Re), which seems to be a very promising method, suffers from the inherent weekness that it has not been possible as yet to determine the half-life of Re^{187} with a high degree of accuracy. The value used by W. Herr for the calculation of ages quoted in this paper, $T = 6.2x\ 10^{10}$ years, is inferred from the dating of molybdenite deposits by other methods. The Re/Os ages of Norwegian minerals would appear to be somewhat too low, and a half-life 20% higher or so would seem to make them fit better into the time scheme. However, data is too sparse and too vague for anything approaching a dogmatic statement to be made to this effect.

Also, some of the apparent ages given in Table 1 are determined for minerals which are either highly altered or inaccurately located. These data have, of course, a very limited value, if any, from the geochronological point of view.

In Table 1 apparent ages which will be discussed below are marked with an asterisk.

Table 1. List of age determinations.

Informations are given in the following order: apparent age, mineral, method applied, age determination by ...... and literature reference, locality, specimen collected or supplied by ......

136 m. y.	Zircon. Lead-alpha. U. S. Geological Survey. Larvik. T. F. W. Barth & H. Neumann.
160 m. y.	Zircon. Lead-alpha. U. S. Geological Survey. Barkevik. T. F. W. Barth & H. Neumann.
166 m. y.	Zircon. Lead-alpha. U. S. Geological Survey. Låven. T. F. W. Barth & H. Neumann.
*216 m. y.	Zircon. Th^{232}/Pb^{208} H. Faul (1959). Oslo nordmarkite, Trondheimsveien, large new road cut near Oslo city limit. H. Faul.
231 m. y.	Zircon. Lead-alpha. U. S. Geological Survey. Barkevik. T. F. W. Barth & H. Neumann.
*235 ± 10% m. y.	Molybdenite. Re/Os. W. Herr & E. Merz (1958). Sørumsåsen Røyken. H. Neumann & B. Nilssen.
*243 m. y.	Thorite. U^{238}/Pb^{206}. A. O. Nier (1939). Brevig.
244 m. y.	Uranothorite. Th^{232}/Pb^{208}. Pb^{208} from molecular weight of Pb. E. Gleditsch & B. Qviller (1932). Pegmatite dyke. Kragerø.

250 m. y.	Zircon. Lead-alpha. U. S. Geological Survey. Mörjefiord. T. F. W. Barth & H. Neumann.
*259 m. y.	Zircon. U^{238}/Pb^{206}. H. Faul (1959). Oslo nordmarkite, Trondheimsveien, large new road cut near Oslo city limit. H. Faul.
*259 m. y.	Biotite. K—Ar. H. Faul (1959). Porphyritic granite, road cut near Skoglyst, Drammen. H. Faul.
269 + 10 — 30 m. y.	Zircon. Lead-alpha. S. Moorbath. Barkevik, Langesundsfiord (No. 2). H. Neumann.
279 + 10 — 30 m. y.	Zircon. Lead-alpha. S. Moorbath. Seiland, plumasite pegmatite. H. Neumann.
*284 m. y.	Biotite. K—Ar. S. S. Goldich. Biotite from essexite porphyrite, Sande, Vestfold. O. Holtedahl & B. Nilssen.
285 + 10 — 30 m. y.	Zircon. Lead-alpha. S. Moorbath. Barkevik, Langesundsfiord (No. 1). H. Neumann.
294 + 15 — 40m. y.	Zircon. Lead-alpha. S. Moorbath. Seiland (No. 1). H. Neumann.
310 m. y.	Uraninite. U, Th/Pb without isotope determinations. I. Th. Rosenqvist (1947). Pegmatite, Tor's mine, Vats, in the county of Ryfylke. I. Th. Rosenqvist.
*315 m. y.	Lepidomelane. K—Ar. A. A. Polkanov & E. K. Gerling. Lepidomelane from nepheline syenite pegmatite dyke. Langesundsfiord. Geological Museum.
329 m. y.	Feldspar. K—Ar. W. Kley & P. Schmidlin. Granite, «Østfold granite», Seut, near Fredrikstad. H. Neumann & M. A. Sellevoll.
331 + 15 — 40 m. y.	Zircon. Lead-alpha. S. Moorbath. Fredriksvern. H. Neumann.
*355 m. y.	Thorite. Th^{232}/Pb^{208}. A. O. Nier (1939). Brevig.
365 m. y.	Zircon. Lead-alpha. U. S. Geological Survey. Tellenes (I). T. F. W. Barth & H. Neumann.
366 + 20 — 40 m. y.	Zircon. Lead-alpha. S. Moorbath. Seiland, canadite pegmatite. H. Neumann.
390 m. y.	Zircon. Lead-alpha. U. S. Geological Survey. Tellenes (II). T. F. W. Barth & H. Neumann.
*405 m. y.	Mica. K—Ar. A. A. Polkanov and E. K. Gerling. Porphyritic granite. Bindal, Tverrådalen, Namdalen. Chr. Oftedahl. 1958.
413 m. y.	Feldspar. K—Ar. W. Kley and P. Schmidlin. Hollaite pegmatite, Fen. H. Neumann.
420 m. y.	Koppite. Th/Pb without isotope determinations. E. Sæther (1957). Søvite, Fen. E. Sæther.
430 m. y.	Uranothorite. U/Pb^{206}. Pb^{206} from molecular weight. E. Gleditsch and B. Quiller. (1932). Pegmatite dyke, Kragerø.
*434 m. y.	Biotite. K—Ar. A. A. Polkanov and E. K. Gerling. Biotite from pegmatite. Tveit. Gneiss, Sotra, W. of Bergen. A. Kvale 1958.
437 m. y.	Feldspar. K—Ar. W. Kley and P. Schmidlin. Pegmatite, Lakssvelefjell, Egersund formation. P. Michot.
*450 m. y.	Euxenite. U^{238}/Pb^{206}. J. L. Kulp and W. R. Eckelmann. (1957) Pegmatite, Kalstad, Kragerø. H. Neumann.
*450 m. y.	Muscovite. K—Ar. A. A. Polkanov and E. K. Gerling. Pegmatite, Lia, Laksevåg. Gneisses W of Bergen. A. Kvale, 1958.

460 m. y.	Zircon. Lead-alpha. U. S. Geological Survey. Søvite, Fen. T. F. W. Barth and H. Neumann.
484 m. y.	Feldspar. K—Ar. W. Kley and P. Schmidlin. Pegmatite, Rømteland. H. Neumann and T. Sverdrup.
*485 ± 5 m. y.	Euxenite. U^{238}/Pb^{206}. J. L. Kulp and W. R. Eckelmann (1957). Pegmatite, Rømteland. H. Neumann and T. Sverdrup.
*495 ± 30 m. y.	Thorite. Th^{232}/Pb^{208}. J. L. Kulp and W. R. Eckelmann (1957). Pegmatite, Rømteland. H. Neumann and T. Sverdrup.
501 m. y.	Feldspar. K—Ar. W. Key and P. Schmidlin. Pegmatite, Halvorsrud, Råde, Østfold. H. Neumann and B. Nilssen.
508 m. y.	Feldspar. K—Ar. W. Kley and P. Schmidlin. Pegmatite, Ålgård, Egersund. P. Michot.
520 m. y.	Zircon. Lead-alpha. U. S. Geological Survey. Stjernø, W. Finnmark. T. F. W. Barth and H. Neumann.
*530 m. y.	Euxenite. U^{235}/Pb^{207}. J. L. Kulp and W. R. Eckelmann (1957). Pegmatite, Kalstad, Kragerø. H. Neumann.
530 ± 50 m. y.	Zircon. Lead-alpha. Henry Faul. (1959). Carbonatite, Søve, Fen. Sv. Svinndal.
*540 ± 10% m. y.	Molybdenite. Re/Os. W. Herr and E. Merz. Rødsand, Møre. H. Neumann.
560 m. y.	Feldspar. K—Ar. W. Kley and P. Schmidlin. Farsundite, Rømteland. H. Neumann and T. Sverdrup.
*560 ± 7 m. y.	Euxenite. U^{235}/Pb^{207}. J. L. Kulp and W. R. Eckelmann (1957). Pegmatite, Rømteland. H. Neumann and T. Sverdrup.
560 m. y.	Zircon. Lead-alpha. U. S. Geological Survey. Melkedøla, Bygdin. T. F. W. Barth and H. Neumann.
*565 ± 10% m. y.	Molybdenite. Re/Os. W. Herr and E. Merz (1958). Oterstrand, Gildeskål. H. Neumann.
*565 m. y.	Biotite. K—Ar. Henry Faul (1959). Carbonatite, Søve mine, Fen. H. Faul.
570 m. y.	Zircon. Th/Pb without isotope determinations. E. Sæther (1957). Søvite, Tufte quarry, Fen. E. Sæther.
570 m. y.	Koppite. Th/Pb without isotope determinations. E. Sæther (1957). Søvite, Cappelen's quarry, Fen. E. Sæther.
*582 m. y.	Muscovite. K—Ar. A. A. Polkanov and E. K. Gerling. Pegmatite, in gneiss. Loen, Nordfjord. A. Kvale 1958.
587 m. y.	Feldspar. K—Ar. W. Kley and P. Schmidlin. Gneiss. Spangereid. E. of Egersund formation. H. Neumann and T. Sverdrup.
*590 m. y.	Mica. K—Ar. A. A. Polkanov and E. K. Gerling. Pegmatite, Ortnevik, Sogn. North western gneiss area. A. Kvale. 1958.
*590 m. y.	Mica. K—Ar. A. A. Polkanov and E. K. Gerling. Søvite. Fen. Sv. Svinndal 1958.
590 m. y.	Columbite. Th/Pb without isotope determinations. E. Sæther (1957). Søvite, Tufte quarry, Fen. E. Sæther.
*603 m. y.	Mica. K—Ar. A. A. Polkanov and E. K. Gerling. Søvite, Fen. Sv. Svinndal.
*610 ± 50 m. y.	Thorite. $Pb^{207/206}$. H. Fr. Ehrenberg. Pegmatite dyke, Tvedestrand.
613 m. y.	Feldspar. K—Ar. W. Kley and P. Schmidlin. Granite. Iddefjord, Østfold. H. Neumann and B. Nilssen.
*615 ± 10% m. y.	Molybdenite. Re/Os. W. Herr and E. Merz (1958). Thoreby, Varteig. H. Neumann.

*621 ± 10% m. y.	Molybdenite. Re/Os. W. Herr and E. Merz. Tarjeisberg, Telemark. H. Neumann and O. Adamson.
640 ± 50 m. y.	Feldspar. K—Ar. W. Herr. «Young red granite», Torset, Langøy, Nordland. K. Heier.
650 m. y.	Feldspar. K—Ar. W. Herr. Svolvær granite, S. Følstad, Lofoten. K. Heier.
*657 ± 10% m. y.	Molybdenite. Re/Os. W. Herr and E. Merz. Bandaksli, Telemark. H. Neumann.
672 m. y.	Feldspar. K—Ar. W. Kley and P. Schmidlin. Granite, Hobøl, Østfold. H. Neumann and B. Nilssen.
*676 ± 10% m. y.	Molybdenite. Re/Os. W. Herr and E. Merz (1958). Riehammeren, Berge. H. Neumann and B. Nilssen.
*679 ± 10% m. y.	Molybdenite. Re/Os. W. Herr and E. Merz (1958). Hosås, Risør. H. Neumann and K. Heier.
*687 ± 10% m. y.	Molybdenite. Re/Os. W. Herr and E. Merz (1958). Dalen, Telemark. H. Neumann and B. Nilssen.
*691 ± 10% m. y.	Molybdenite. Re/Os. W. Herr and E. Merz. Dalen, Telemark. H. Neumann and B. Nilssen.
*700 ± 10% m. y.	Molybdenite. Re/Os. W. Herr and E. Merz. Rollag, Nummedal. H. Neumann and K. Heier.
*709 ± 10% m. y.	Molybdenite. Re/Os. W. Herr and E. Merz (1958). Rollag, Nummedal. H. Neumann and K. Heier.
720 m. y.	Zircon. Lead-alpha. U. S. Geological Survey. Solberg, Tvedestrand. T. F. W. Barth and H. Neumann.
*740 ± 6 m. y.	Thorite. U^{238}/Pb^{206}. J. L. Kulp and W. R. Eckelmann (1957). Pegmatite, Rømteland. H. Neumann and T. Sverdrup.
*755 ± 65 m. y.	Gadolinite. RaD/Pb. W. Herr, E. Merz, P. Eberhardt and P. Signer (1958). Pegmatite dyke, Frikstad, Iveland. H. Neumann.
*759 m. y.	Biotite. K—Ar. W. Kley and P. Schmidlin. Gneiss. Remesvig, east of Egersund formation. H. Neumann and T. Sverdrup.
*760 ± 8 m. y.	Thorite. U^{235}/Pb^{207}. J. L. Kulp and W. R. Eckelmann (1957). Pegmatite, Rømteland. H. Neumann and T. Sverdrup.
760 m. y.	Zircon. Lead-alpha. U. S. Geological Survey. Solberg Arendal. T. F. W. Barth and H. Neumann.
*772 m. y.	Mica. K—Ar. A. A. Polkanov and E. K. Gerling. Granite, Ara-odden, Telemark. O. A. Broch, 1958.
*776 m. y.	Mica. K—Ar. A. A. Polkanov and E. K. Gerling. Granite. Onsøy near Fredrikstad. O. A. Broch, 1958.
*777 m. y.	Biotite. K—Ar. A. A. Polkanov and E. K. Gerling. Pegmatite, Telemark gneiss. S. shore of lake Kviteseid. O. A. Broch 1958.
*802 m. y.	Mica. K—Ar. A. A. Polkanov and E. K. Gerling. Granite. Solli, Råde, Østfold. O. A. Broch, 1958.
804 ± 10% m. y.	Molybdenite. Re/Os. W. Herr and E. Merz (1958). Stavanger
812 m. y.	Feldspar. K—Ar. W. Kley and P. Schmidlin. Gneiss. Heller farm, Askim. H. Neumann and B. Nilssen.
*820 ± 30 m. y.	Gadolinite. Pb^{207}/Pb^{206}. W. Herr and E. Merz, (1958). Pegmatite dyke, Frikstad, Iveland. H. Neumann.
*823 m. y.	Mica. K—Ar. A. A. Polkanov and E. K. Gerling. Granite, Iddefjord. O. A. Broch 1958.
*824 m. y.	Mica. K—Ar. A. A. Polkanov and E. K. Gerling. Granite gneiss. Gol, Hallingdal. O. A. Broch 1958.
*830 ± 25 m. y.	Thorite. Pb^{207}/Pb^{206} J. L. Kulp and W. R. Eckelmann (1957). Pegmatite, Rømteland. H. Neumann and T. Sverdrup.

830 m. y.	Zircon. Lead-alpha. U. S. Geological Survey. Næs skjerp, Arendal. T. F. W. Barth and H. Neumann.
*840 m. y.	Cleveite. Th^{232}/Pb^{208}. A. O. Nier (1939). Auselmyren, Holt, Aust-Agder.
*852 m. y.	Biotite. K—Ar. A. A. Polkanov and E. K. Gerling. Pegmatite, Bjertnes feldspar quarry, Krødsherad. O. A. Broch.
*857 m. y.	Mica. K—Ar. A. A. Polkanov and E. K. Gerling. Telemark. Granite gneiss. O. A. Broch. (Same sample as 869 m. y.).
*862 ± 10% m. y.	Molybdenite. Re/Os. W. Herr and E. Merz (1958). Kobbernuten, Bykle. H. Neumann.
*869 m. y.	Mica. K—Ar. A. A. Polkanov and E. K. Gerling. Granite gneiss. Gol, Hallingdal. O. A. Broch 1958.
*874 m. y.	Biotite. K—Ar. A. A. Polkanov and E. K. Gerling. Pegmatite. By road from Vik (near Grimstad) to Froland. O. A. Broch. 1958.
879 m. y.	Feldspar. K—Ar. W. Kley and P. Schmidlin. Gneiss. Magnor. H. Neumann and B. Nilssen.
*880 m. y.	Biotite. K—Ar. A. A. Polkanov and E. K. Gerling. Pegmatite, Håverstad, Iveland. O. A. Broch 1958.
*880 ± 30 m. y.	Lepidolite. Rb—Sr. J. L. Kulp. Pegmatite, Tørdal. H. Neumann and B. Nilssen.
*882 ± 10% m. y.	Molybdenite. Re/Os. W. Herr and E. Merz (1958). Pegmatite, Tveit, Iveland. H. Neumann.
*882 m. y.	Mica. K—Ar. A. A. Polkanov and E. K. Gerling. Birkeland granite, Sennomstad bridge S. of Herefoss. O. A. Broch 1958.
*884 ± 75 m. y.	Blomstrandine. RaD/Pb. W. Herr and E. Merz. Pegmatite dyke, Kåbuland, Iveland. H. Neumann.
*890 m. y.	Mica. K—Ar. A. A. Polkanov and E. K. Gerling. Gneiss. Ål railway station. Hallingdal. O. A. Broch 1958.
*890 ± 5 m. y.	Uraninite. U^{238}/Pb^{206}. J. L. Kulp and W. R. Eckelmann (1957). Pegmatite, Rømteland. H. Neumann and T. Sverdrup.
*892 ± 8 m. y.	Uraninite. U^{235}/Pb^{207}. J. L. Kulp and W. R. Eckelmann (1957). Pegmatite, Rømteland. H. Neumann and T. Sverdrup.
895 ± 5% m. y.	Feldspar. K—Ar. W. Gentner and W. Kley (1957). Pegmatite dyke, Hyttåsen, Hobøl. H. Neumann and B. Nilssen.
*900 ± 30 m. y.	Uraninite. Th^{232}/Pb^{208}. J. L. Kulp and W. R. Eckelmann (1957). Pegmatite, Rømteland. H. Neumann and T. Sverdrup.
*900 m. y.	Mica. K—Ar. A. A. Polkanov and E. K. Gerling. Gneiss. Omre, between Grimstad and Lillesand. O. A. Broch. 1958.
*900 m. y.	Lepidolite. Rb/Sr. S. R. Taylor. Tørdal, Telemark. H. Neumann.
*904 m. y.	Muscovite. K—Ar. A. A. Polkanov and E. K. Gerling. Pegmatitic rock. Tor's mine, Vats, Ryfylke. A. Kvale.
*904 m. y.	Mica. K—Ar. A. A. Polkanov and E. K. Gerling. Mica from pegmatite. Løvrak, Aust-Agder. O. A. Broch 1958.
*905 m. y.	Muscovite. K—Ar. A. A. Polkanov and E. K. Gerling. Pegmatite, Åmli. O. A. Broch 1958.
910 m. y.	Zircon. Lead-alpha. U. S. Geological Survey. Skarvvann, Seiland. T. F. W. Barth and H. Neumann.
*910 ± 20 m. y.	Euxenite. Pb^{207}/Pb^{206}. J. L. Kulp and W. R. Eckelmann (1957). Pegmatite, Rømteland. H. Neumann and T. Sverdrup.

*920 ± 20 m. y.	Uraninite. Pb^{207}/Pb^{206}. J. L. Kulp and W. R. Eckelmann (1957). Pegmatite, Rømteland. H. Neumann and T. Sverdrup.
*920 ± 35 m. y.	Euxenite. Th^{232}/Pb^{208}. J. L. Kulp and W. R. Eckelmann (1957). Pegmatite, Rømteland. H. Neumann and T. Sverdrup.
*920 m. y.	Uraninite. Pb^{207}/Pb^{206}. S. Moorbath. Pegmatite, Rømteland. H. Neumann and T. Sverdrup.
*920 ± 60 m. y.	Blomstrandine. Pb^{207}/Pb^{206}. W. Herr and E. Merz (1958). Pegmatite dyke, Kåbuland, Iveland. H. Neumann.
*920 m. y.	Uraninite. Pb^{207}/Pb^{206}. S Moorbath. Pegmatite, Karlshus, Østfold. H. Neumann.
*927 m. y.	Biotite. K—Ar. A. A. Polkanov and E. K. Gerling. Pegmatite, Grøsle. O. A. Broch.
*927 m. y.	Mica. K—Ar. A. A. Polkanov and E. K. Gerling. Granite. Flå granite. Above Gulsvik station. O. A. Broch 1958.
*929 m. y.	Biotite. K—Ar. W. Kley and P. Schmidlin. Gneiss. Heller farm, Askim. H. Neumann and B. Nilssen.
*930 m. y.	Mica. K—Ar. A. A. Polkanov and E. K. Gerling. Granite. Killandsvann, Herefoss. O. A. Broch 1958.
*930 m. y.	Biotite. K—Ar. A. A. Polkanov and E. K. Gerling. Pegmatite. O. A. Broch. (Same sample as 927 m. y.).
930 m. y.	Zircon. Lead-alpha. U. S. Geological Survey. Skarvberg, Seiland. T. F. W. Barth and H. Neumann.
*940 m. y.	Euxenite. Pb^{207}/Pb^{206}. J. L. Kulp and W. R. Eckelmann (1957). Pegmatite, Kalstad, Kragerø. H. Neumann.
*943 m. y.	Mica. K—Ar. A. A. Polkanov and E. K. Gerling. Granite. Flå granite. Ospeholt in Hedal, Opland. O. A. Broch, 1958.
*946 m. y.	Muscovite. K—Ar. A. A. Polkanov and E. K. Gerling. Pegmatite, Nordby, Rakkestad. O. A. Broch 1958.
*950 ± 50 m. y.	Microcline. Rb—Sr. J. L. Kulp. Pegmatite, Tørdal. H. Neumann.
*952 m. y.	Mica. K—Ar. A. A. Polkanov and E. K. Gerling. Granite. Flå-granite. Gryte 6 km S. of Viken church, Sperillen., O. A. Broch 1958.
*956 m. y.	Mica. K—Ar. A. A. Polkanov and E. K. Gerling. Granite. Birkeland granite. Skiftenes, Herefoss. O. A. Broch 1958.
*962 ± 10% m. y.	Molybdenite. Re/Os. W. Herr and E. Merz. (1958). Pegmatite, Tuftan, Iveland. H. Neumann.
*965 m. y.	Muscovite. K—Ar. W. Gentner and W. Kley. (1957). Pegmatite dyke, Hyttåsen, Hobøl. H. Neumann and B. Nilssen.
*966 m. y.	Biotite. Rb—Sr. A. A. Polkanov and E. K. Gerling. Pegmatite. Grøsle. Feldspar quarry. O. A. Broch.
968 m. y.	Broeggerite. U/Pb without isotope determination. Ellen Gleditsch. Pegmatite, Karlshus, Råde.
*970 m. y.	Muscovite. K—Ar. A. A. Polkanov and E. K. Gerling. Pegmatite, Løvrak, Aust-Agder. O. A. Broch 1958.
970 ± 80 m. y.	Feldspar. K—Ar. W. Herr. Tarjeisberg (F), Telemark. H. Neumann and O. Adamson.
*977 m. y.	Muscovite. K—Ar. A. A. Polkanov and E. K. Gerling. Pegmatite, Bjertnes, Krødsherad. O. A. Broch 1958.
*980 m. y.	Euxenite. Th^{232}/Pb^{208} J. L. Kulp and W. R. Eckelmann (1957). Pegmatite, Kalstad, Kragerø. H. Neumann.
*990 m. y.	Mica. K—Ar. A. A. Polkanov and E. K. Gerling. Veined gneiss. By the road from Hamremoen to Noresund. O. A. Broch 1958.

*990 m. y.	Mica. K—Ar. A. A. Polkanov and E. K. Gerling. Gneiss. (Migmatite). Between N. Herefoss and Hanefoss. O. A. Broch 1958.
*1007 m. y.	Mica. K—Ar. A. A. Polkanov and E. K. Gerling. Gneiss. O. A. Broch 1958.
1011 m. y.	Broeggerite. U + Th/Pb without isotope determinations and without molecular weight of Pb. E. Føyn (1938). Pegmatite, Karlshus, Råde.
*1016 m. y.	Mica. K—Ar. A. A. Polkanov and E. K. Gerling. Gneiss. Valebø, near Fen area. Sv. Svinndal.
1018 m. y.	Cleveite. U/Pb without isotope determinations. Ellen Gleditsch (1925). Pegmatite, near Arendal.
1020 ± 70 m. y.	Microcline. K—Ar. A. Holmes, H. A. Shillibeer (1955). Pegmatite, Arendal.
*1030 m. y.	Mica. K—Ar. A. A. Polkanov and E. K. Gerling. Coarse grained granite. By the road from Vik, near Grimstad, to Froland. O. A. Broch 1958.
*1040 m. y.	Biotite. K—Ar. S. S. Goldich. Arendalite, Langsev. S. Norway. H. Neumann and B. Nilssen.
*1041 m. y.	Phlogopite. K—Ar. W. Kley and P. Schmidlin. Pegmatite, Snarum. H. Neumann and O. B. Jøsang.
1043 m. y.	Cleveite. U/Pb without isotope determinations. Ellen Gleditsch (1925). Pegmatite, Iveland.
*1048 m. y.	Biotite. K—Ar. A. A. Polkanov and E. K. Gerling. Gneiss rich in mica. By the road from Hønefoss to Hamre, Heradsbygd. O. A. Broch 1958.
*1052 m. y.	Muscovite. K—Ar. A. A. Polkanov and E. K. Gerling. Gneiss rich in mica. O. A. Broch 1958. (Same sample as 1048 m. y.)
*1060 m. y.	Cleveite. U^{238}/Pb^{206}. S. Moorbath. 1960. Pegmatite, Auselmyra, Aust-Agder. H. Neumann.
*1070 m. y.	Cleveite. U^{235}/Pb^{207}. S. Moorbath 1960. Pegmatite, Auselmyra, Aust-Agder. H. Neumann.
*1085 m. y.	Cleveite. U^{238}/Pb^{206}. A. O. Nier, (1939). Pegmatite, Auselmyra, Holt, Aust-Agder.
*1090 m. y.	Cleveite. Pb^{207}/Pb^{206}. A. O. Nier. Pegmatite from Auselmyra, Holt, Aust-Agder.
*1090 m. y.	Cleveite. Pb^{207}/Pb^{206}. S. Moorbath. Pegmatite, Auselmyra, Aust-Agder. H. Neumann.
*1110 m. y.	Cleveite. Th^{232}/Pb^{208}. S. Moorbath. Pegmatite, Auselmyra, Aust-Agder. H. Neumann.
1193 m. y.	Cleveite. U + Th/Pb without isotope analysis and without molecular weight of Pb. E. Føyn (1938). Pegmatite, Aust-Agder.
1251 m. y.	Cleveite. U/Pb without isotope determinations. R. Bakken, E. Gleditsch and A. C. Pappas (1948). Pegmatite, Auselmyren.
1254 m. y.	Cleveite. U + Th/Pb without isotope determinations and without molecular weight of Pb. E. Føyn (1938). Pegmatite, Arendal.
1269 m. y.	Cleveite. U + Th/Pb Without isotope determinations and without molecular weight of Pb. E. Føyn (1938). Pegmatite, Auselmyren, Aust-Agder.
1283 m. y.	Cleveite. U + Th/Pb without determ. of isotopes nor mol. weight. R. Bakken and E. Gleditsch (1938). Pegmatite, Auselmyren, Holt.

1294 m. y.	Cleveite. U + Th/Pb without determ. of isotopes nor mol. weight of Pb. R. Bakken and E. Gleditsch (1938). Pegmatite, Auselmyren, Holt.
1300 m. y.	Allanite. Th/Pb without isotope determinations. N. Jordanov (1957). Pegmatite, Hitterø.
1308 m. y.	Cleveite. U + Th/Pb without determ. of isotopes nor molecular weight of Pb. R. Bakken and E. Gleditsch. (1938). Pegmatite, Auselmyren, Holt.
*1560 ± 10% m. y.	Molybdenite. Re/Os. W. Herr and E. Merz. Tarjeisberg, Telemark. H. Neumann and O. Adamson.
1620 ± 120 m. y.	Feldspar. K—Ar. W. Herr. Tarjeisberg, Telemark. H. Neumann and O. Adamson.
2080 ± 10% m. y.	Molybdenite. Re/Os. W. Herr and E. Merz (1958). Lofoten.
*2290 ± 10% m. y.	Molybdenite. Re/Os. W. Herr and E. Merz (1958). Vatterfjord, Lofoten, county of Nordland. H. Neumann.

Oslo area rocks.

The following age determinations have been made by different methods (see Table 1): 355, 315, 284, 259, 259, 243, 235, and 216 m. y. At present the author is not prepared to offer any comments to these apparent ages.

Caledonian rocks.

Three K/Ar determinations of Caledonian rocks by A. A. Polkanov and E. K. Gerling[1] give the apparent ages 450, 434, and 405 m. y. The two molybdenites with Re/Os ages 540 and 565 m. y. done by W. Herr[2] are also probably of Caledonian origin.

The two micas from pegmatites in Nordfjord and Sogn with apparent K/Ar ages 582 and 590 m. y. (A. A. Polkanov and E. K. Gerling) may be of Caledonian origin but are probably older. Argon built up in the mineral previously may have been expelled during a later period of Caledonian orogeny and metamorphism; thus producing an apparent age lower than the true age of formation.

Søvite, Fen area.

K/Ar determinations of large unaltered mica crystals in the carbonatite (Søvite) in the Fen area have been made by H. Faul (1959) who found an apparent age of 565 m. y., and by A. A. Polkanov and E. K. Gerling who found 590 m. y. and 603 m. y. by two determinations of the same specimen.

Following the revised time-scale of A. Holmes (1959) an early Cambrian age is indicated.

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[1] Laboratory for pre-Cambrian Geology, Leningrad.

[2] Max Planck Institut für Chemie, Mainz.

Molybdenite deposits supposed to be related to the «Telemark granite» (see later).

W. Herr and E. Merz (1958, and personal communications) have dated eight molybdenites by the Re/Os method. These were obtained from molybdenite deposits which are presumed to have been deposited by late hydrothermal solutions emanating from the youngest member of the rock series, which is generally referred to as the «Telemark granite». The following apparent ages were found: 862, 709, 700, 691, 687, 679, 676, and 657 m. y. The average of these values is 708 million years, or, if the highest value (in fact the Kobbermuten deposit, 862 m. y., may have a different origin) and the lowest value are excluded, 690 million years, a value which may appear somewhat low.

The Østfold granite.

Three K/Ar age determinations have been performed by A. A. Polkanov and E. K. Gerling on micas from the Østfold granite (776, 802, 823 m. y.) of which two are from the same sample (802 and 823 m. y.). The average of the three determinations is 800 m. y.

An age of approximately 800 million years for the Østfold granite is not inconsistent with age determinations carried out by other investigators on the same granite which outcrops on the Swedish side of the border, where it is called the Bohus granite.

The Thoreby molybdenite deposit has been supposed to be related to the Østfold granite. The apparent Re/Os age of 615 ± 10% m. y. (W. Herr and E. Merz, 1958) is contradictory to this supposition.

Pegmatite from Vik, near Grimstad.

Biotite from a pegmatite at Vik, near Grimstad was K/Ar dated by A. A. Polkanov and E. K. Gerling and has an apparent age of 874 m. y. The pegmatite is located in the Kongsberg—Bamble area close to a coarse grained granite with an apparent age of 1030 m. y.

The same geological events which led to the formation of this pegmatite may have modified the Ar content of mica in the banded gneiss from Omre (between Grimstad and Lillesand) to give this rock an apparent age of 900 m. y. (K/Ar, A. A. Polkanov and E. K. Gerling). On the other hand this banded gneiss of the Kongsberg—Bamble area may have formed at that time, a problem which cannot be solved without further investigations.

The «Telemark granite».

The «Telemark granite» is a somewhat unfortunate name for types of granitic rocks covering a great part of the South Norwegian pre-Cambrian area. The rocks are mostly gneissic and «Telemark gneisses» would be a better name, while there are also younger members of the suite which are genuine homogeneous granites, as well as pegmatites.

Four K/Ar determinations performed by A. A. Polkanov and E. K. Gerling on mica from the gneisses give the apparent ages 890, 869, 857, and 824 m. y. The highest apparent age, 890 million years, is probably a fair approximation to the age of formation of the older rocks of this suite; while the younger apparent ages may be too low, because of a loss of Ar from the minerals and rocks concerned caused by later geological events (as for example the formation of the youngest homogeneous granites of the same series of rocks).

A nearly homogeneous granite from Ara-odden in Telemark, called by O. A. Broch, who collected the analyzed specimen, «a younger, probably palingeneous granite» has an apparent age of 772 m. y., and a pegmatite on the southern shore of lake Kviteseid, an apparent age of 777 m. y. (both on mica, K/Ar, A. A. Polkanov and E. K. Gerling).

Pegmatitic rock from Tor's mine, Vats.

One K/Ar dating of a muscovite from Tor's mine has been done by A. A. Polkanov and E. K. Gerling who found an apparent age of 904 million years. A possible Caledonian origin has been discussed for the Vats pegmatite and the surrounding rocks, a geological interpretation which is strongly contradicted by this figure.

Pegmatites of the Iveland district.

W. Herr and E. Merz (1958 and personal communications) have made the following age determinations of minerals from the pegmatite dykes in Iveland:

RaD/Pb method, gadolinite, Frikstad	755 ± 65 m. y.
Pb^{207}/Pb^{206} method, gadolinite, Frikstad	820 ± 30 m. y.
RaD/Pb method, blomstrandine, Kåbuland	844 ± 36 m. y.
Pb^{207}/Pb^{206} method, blomstrandine, Kåbuland	920 ± 60 m. y.
Re/Os method, molybdenite, Tveit	882 ± 70 m. y.
Re/Os method, molybdenite, Tuftan	962 ± 80 m. y.

A. A. Polkanov and E. K. Gerling report a K/Ar age of biotite from Håverstad of 880 m. y.

More data are desirable but tentatively an approximate age of 880—920 million years may be assigned to the Iveland pegmatites.

The Tørdal pegmatite.

J. L. Kulp[1] has dated lepidolite and microcline from the Tørdal dykes by the Rb—Sr method and found the ages 880 ± 30 m. y. and 950 ± 50 m. y. respectively. S. R. Taylor[2] found an age of 900 million years, for the lepidolite using the same method. The average of these three determinations 910 million years, is probably fairly close to the correct age of the dykes. The Tørdal pegmatite is located in the Telemark area south of the lake Flåvann.

The Rømteland pegmatite.

The Rømteland pegmatite is located within a large mass of farsundite, (a biotite and hornblende-bearing quartz-monzonite). The pegmatite dyke is mineralogically closely related to the farsundite, and is probably a coarser grained facies of this rock. The farsundite may or may not be genetically related to the anorthosites, norites and charnockites of the Egersund—Sogndal formation. It has also been tentatively grouped with the «young» granitic bodies of the southern pre-Cambrian area such as the Birkeland granite.

Uraninite, euxenite, and thorite from this pegmatite have been studied by J. L. Kulp and W. R. Eckelmann (1957) applying U—Th—Pb methods. They conclude that the age of these minerals is 920 ± 20 million years, and this figure would appear to be amongst the best founded and most reliable of the age data on Norwegian minerals and rocks. The reader is referred to the above mentioned paper for details.

The Karlshus pegmatite.

A Pb^{207}/Pb^{206} determination of uraninite (brøggerite) from this dyke by S. Moorbath[3] indicates an age of 920 m. y. for this deposit. (An older U/Pb age without isotope determination by E. Gleditsch gave 968 m. y.) The Karlshus dyke is located a short distance north of the Østfold granite, with which it was earlier supposed to be genetically related; an interpretation which is made impossible by the younger age (800 m. y.) of that granite.

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[2] Then at the Department of Geology, Oxford.
[3] Department of Geology, Oxford.

The pegmatite dyke at Hyttåsen, Hobøl, 965 m. y. (muscovite, K—Ar, W. Gentner and W. Kley (1957)), the pegmatite dyke at Nordby, Rakkestad, 946 m. y. (muscovite, K—Ar, A. A. Polkanov and E. K. Gerling) and the gneiss from Heller farm, Askim, 929 m. y., (biotite, K—Ar, W. Kley and P. Schmidlin[1]), all in the county of Østfold, may belong to the same geological epoch as the Karlshus pegmatite.

The Birkeland granite, the Flå granite, and related rocks.

The Birkeland granite has been dated by three K—Ar determinations (882, 930, 956 m. y.) of the granite itself, and five K—Ar determinations (904, 905, 927, 930, 970 m. y.) and one Rb—Sr determination (966 m. y.) of pegmatites supposed to be genetically related to it. In all cases micas from the rocks mentioned were analyzed by A. A. Polkanov and E. K. Gerling.

The average of these nine determinations is 930 m. y. with a variation from 882 to 970 m. y.

The Flå granite has been dated by three K—Ar determinations on mica from the granite (927, 943, 952 m. y.) and two from a related pegmatite (852, 977 m. y.) done by A. A. Polkanov and E. K. Gerling. The average of the five determinations is 930 m. y. with a variation from 852 to 977 m. y.

The Birkeland and Flå granites have a similar geological situation on or near the junction between the Kongsberg—Bamble area and the Telemark area, but are otherwise rather different chemically and mineralogically as well as in appearance. They have consequently not been considered by Norwegian geologists as being related in any way. Nevertheless they seem to be contemporaneous with an age of approximately 930 million years.

The Telemark area veined gneiss with a K—Ar age of 990 m. y. from the road from Hamremoen to Noresund is situated not too far from the Flå granite and is described by O. A. Broch, who collected the analyzed specimen, as a migmatite «with vein material possibly

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from the Flå granite, ...» Probably this is an older gneiss which was transformed in one way or another at the time of formation of the Flå granite and then partly lost its content of earlier formed Ar. Its slightly higher apparent age (approximately 990 m. y. as compared to 930 m. y.) may not be entirely fortuitous.

The apparent age of 1000 m. y. (990 and 1007 m. y.) of the gneiss between northern Herefoss and the barracks for Hanefoss power station should probably be interpreted in the same way. The distance to the Birkeland granite is about 3 km and the gneiss is situated within the aureole of porphyroblastesis surrounding that granite.

The Kalstad pegmatite near Kragerø.

J. L. Kulp and W. R. Eckelmann (1957) give the following apparent ages for euxenite from the Kalstad dyke: U^{238}/Pb^{206} 450 m. y., U^{235}/Pb^{207} 530 m. y., Pb^{207}/Pb^{206}, 940 m. y. and Th^{232}/Pb^{208} 980 m. y. The ages are discordant and the discordance pattern of euxenite is not too well known. It would, therefore, be highly desirable to have some more data before an age is assigned to this dyke.

The Tarjeisberg molybdenite deposit in Telemark.

W. Herr and E. Merz have dated the Tarjeisberg deposit west of Nisservann in the Telemark area by the Re/Os method. Two different samples of molybdenite were analyzed and gave the apparent ages of 1560 ± 10% m. y. and 621 ± 10% m. y. Two microclines from different sites in the deposit were also dated by W. Herr by the K/Ar method and gave the apparent ages of 1620 ± 120 m. y., and 970 ± 80 m. y.

At present no attempt will be made to interpret these controversial data. Further investigations would certainly seem to be of considerable interest.

The Auselmyra pegmatite, and other rocks of approximately the same age.

Cleveite from this dyke has been dated by A. O. Nier (1939), and by S. Moorbath by U/Pb and Th/Pb methods with the following results:

	U^{238}/Pb^{206}	U^{235}/Pb^{207}	Pb^{207}/Pb^{206}	Th^{232}/Pb^{208}
A. O. Nier	1085 m. y.		1090 m. y.	840 m. y.
S. Moorbath	1060 m. y.	1070 m. y.	1090 m. y.	1110 m. y.

Because of the concordance of the U ages an age of ~ 1090 m. y. can be assigned to this dyke with a high degree of probability. It is situated in the Kongsberg—Bamble area, and the surrounding rocks must be just as old or older than the dyke. Thus 1090 m. y. must be the minimum age of at least some of the rock suites in the Kongsberg—Bamble area.

Based on K—Ar determinations of micas done by A. A. Polkanov and E. K. Gerling, a somewhat lower age 1050 m. y., is indicated for a banded gneiss from the Kongsberg—Bamble area between Hønefoss and Hamre, while a coarse grained granite from the same formation has an apparent age of 1030 m. y. The gneiss at Valebø near the Fen area in the Telemark area gives an age of 1016 m. y.

S. S. Goldich[1] dated biotite from arendalite at Langsev near Arendal by the K—Ar method and found an apparent age of 1040 m. y. in good agreement with the above mentioned results. Arendalite is a metasomatic rock of quartz-hypersthene diorite composition supposed to belong to a younger rock series of the Kongsberg—Bamble area.

Phlogopite from a pegmatite dyke of the Kongsberg—Bamble area in Snarum was dated (K—Ar) by W. Kley and P. Schmidlin, and has an apparent age of 1041 m. y.

Lofoten and Vesterålen islands.

A Re/Os dating by W. Herr and E. Merz (1958) of molybdenite from the Vatterfjord molybdenite deposit give an apparent age of 2290 ± 10% m. y. indicating that there may be a very ancient rock complex in the Lofoten—Vesterålen area. B. J. Gilletti's (1959) recent tentative dating of the Lewisian of Scotland to ~ 2700 m. y. is interesting in this connection.

Feldspars from the «Svolvær Granite», and from a «young red granite» from Torset on Langøy give the apparent K/Ar ages 650 m. y. and 640 m. y. (W. Herr).

These apparent ages must be regarded as minimum ages for the rocks concerned, which may be very much older, and even if they do not confirm the high Re/Os age, they do at least indicate that the two granites are probably of pre-Cambrian age and not of Caledonian origin.

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[1] University of Minnesota.

General remarks.

It will be clear from what is written above that the dating of the geological complexes in Norway is only in its primary stages, and that a lot of work lies ahead before it is possible to make any conclusive statements on the basis of age determinations, especially about the geological history of the pre-Cambrian suites. It is indicated, however, that two epochs have been more important than others, as the geological events of greatest consequence in pre-Cambrian times in this country seem to have taken place during two periods, one from ~ 900 to ~ 950 million years, and another at ~ 1100 million years. It is surprising, that during the reconaissance work done so far there have been no indications of rockforming processes at times ~ 1400 m. y., and ~ 1800 m. y. so common in other parts of the world, and also in areas not too far away.

Another point worthy of note is the following: The pre-Cambrian rocks of south Norway has been divided into three "formations" on the basis of geological investigations, namely the southeastern area or the Østfold formation east of the Oslo graben, and the Kongsberg—Bamble formation and the Telemark formation west of it. (The Egersund—Sogndal formation of anorthositic-charnockitic affinities is a fourth formation on which very little dating work has been done). The relations of these three "formations" to each other have been very vague and problematic, and the time of formation of their rock suites and their «relative ages» have been matters of controversy. It is of great interest that young apparent ages as well as old apparent ages are found in all three formations, with the one exception, that rocks of an apparent age of ~ 1100 m. y. have not as yet been traced in the Østfold formation. It is indicated that the whole of the pre-Cambrian in the south of the country is formed by a number of geological events which were pene-contemporaneous and in principle identical and that the variations in the resulting products were dependent on variations in the pressure and temperature conditions and in chemical environment from one place to another. The division into three (or four) "formations" may be mainly a geographical convenience and be of much lesser genetical importance than formerly anticipated.

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Manuscript received June 7, 1960.
Printed July 1960.

Addendum

While this paper was in print the following age determinations were completed by professor J. L. Kulp of Lamont Geological Observatory, Columbia University, in cooperation with the author.

385 m. y.	Biotite. K–Ar. J. L. Kulp. Gneiss, Dalsnibba, Romsdal. J. L. Kulp.
395 m. y.	Muscovite. K–Ar. J. L. Kulp. Pyrite ore, Bleikvassli, county of Nordland. F. M. Vokes.
405 m. y.	Biotite. K–Ar. J. L. Kulp. Gneiss, Geiranger, Romsdal. J. L. Kulp.
423 m. y.	Biotite. K–Ar. J. L. Kulp. Pegmatite, Røshagen, Selvågfjord, Langøy, Vesterålen. K. S. Heier.
425 m. y.	Muscovite, K–Ar. J. L. Kulp. Pegmatite, Kvamsvåg, Alversund, Hordaland. M. A. Sellevoll.

430 m. y.	Biotite. K—Ar. J. L. Kulp. Grey gneiss, Jægtbøgen, Langøy, Vesterålen. K. S. Heier.
450 m. y.	Biotite. K—Ar. J. L. Kulp. Mica schist, Storelva between Viksfjord and Geirsfjord, Langøy, Vesterålen. K. S. Heier.
575 m. y.	Biotite. K—Ar. J. L. Kulp. Augen gneiss, crossroads between Sandnes and Sandnesodden, Langøy, Vesterålen. K. S. Heier.
585 m. y.	Biotite. K—Ar. J. L. Kulp. Kimberleyite, Steinsrud, Holla, 1 km SW of the Fen area. S. Bergstøl.
815 m. y.	Biotite. K—Ar. J. L. Kulp. "Telemark granite", Sandå, S. Sundsli, Aust-Agder. H. Neumann and B. Nilssen.
825 m. y.	Biotite. K—Ar. J. L. Kulp. Farsundite, Rømteland, Vest-Agder. T. Sverdrup.
839 m. y.	Biotite. K—Ar. J. L. Kulp. "Østfold granite", Iddefjord, Østfold. H. Neumann and B. Nilssen.
850 m. y.	Biotite. K—Ar. J. L. Kulp. Granite, Fevik, Aust-Agder. H. Neumann and B. Nilssen.
850 m. y.	Biotite, K—Ar. J. L. Kulp. Granite, Amtmannsvingen near Tvedestrand, Aust-Agder. H. Neumann and B. Nilssen.
860 m. y.	Muscovite. K—Ar. J. L. Kulp. Pegmatite, Iveland, Vest-Agder. H. Neumann and B. Nilssen.
860 m. y.	Biotite. K—Ar. J. L. Kulp. Granite, Herefoss, Aust-Agder. B. Nilssen.
870 m. y.	Biotite. K—Ar. J. L. Kulp. Gneiss, Flaten, Aust-Agder. H. Neumann and B. Nilssen.
895 m. y.	Sericite. K—Ar. J. L. Kulp. Pegmatite, Bjertnes feldspar quarry, Krødsherad, Buskerud. H. Neumann and B. Nilssen.
915 m. y.	Biotite. K—Ar. J. L. Kulp. Pegmatite, Tarjeisberg, Telemark. H. Neumann and O. Adamson.
925 m. y.	Biotite. K—Ar. J. L. Kulp. Mica schist, NNE Flaten, Aust-Agder. H. Neumann and B. Nilssen.
935 m. y.	Biotite. K—Ar. J. L. Kulp. Pegmatite, feldspar quarry Hella no. 3, Tromøysund, Aust-Agder. H. Neumann and B. Nilssen.
940 m. y.	Biotite. K—Ar. J. L. Kulp. Gneiss, Assevvann, Aust-Agder. H. Neumann and B. Nilssen.
950 m. y.	Biotite. K—Ar. J. L. Kulp. "Flå granite", WNW Hedal church, Buskerud. H. Neumann.
965 m. y.	Biotite. K—Ar. J. L. Kulp. Granite ("Tinn granite"), north of Tinnsjø, Telemark. J. A. Dons.
1010 m. y.	Biotite. K—Ar. J. L. Kulp. Arendalite, Hisøy, Aust-Agder. H. Neumann and B. Nilssen.
1055 m. y.	Muscovite. K—Ar. J. L. Kulp. Pegmatite 650 m WNW of W. Sone church, Modum, Buskerud. O. Jøsang.

1080 m. y.	Biotite. K—Ar. J. L. Kulp. Productive vein, apatite mine, Ødegården Verk, Bamble, Telemark. R. D. Morton.
1105 m. y.	Biotite. K—Ar. J. L. Kulp. Banded gneiss, Hisøy, Aust-Agder. H. Neumann and B. Nilssen.
1105 m. y.	Biotite. K—Ar. J. L. Kulp. Gneiss, Skarerveien, Lørenskog near Oslo, Akershus. H. Neumann and B. Nilssen.
1345 m. y.	Biotite. K—Ar. J. L. Kulp. Arendalite, Langsev, Aust-Agder. H. Neumann and B. Nilssen.

CONTRIBUTIONS TO THE MINERALOGY OF NORWAY

No. 7. Cassiterite in the Bleikvassli ore.

BY

FRANK M. VOKES
(Mineralogisk-Geologisk Museum, Oslo)

Bleikvassli Gruber A/S in Nordland fylke, some 50 kilometres south of Mo i Rana, (Fig. 1) is at the present mining about 100,000 tons per year of pyritic lead-zinc ore. Economic products are lead, zinc and pyrite concentrates. During the course of a systematic mineralogical examination of samples of the ore, the writer detected the presence of small, rounded to euhedral grains of a brown mineral in the heaviest, non-magnetic fractions. Optical and x-ray powder determinations proved this mineral to be cassiterite (SnO_2)[1]. Following this, cassiterite was observed and studied in thin sections of the Bleikvassli ore. Colorimetric determinations of the SnO_2 content of the ore were also made on more than 30 samples. At the same time, a large sample of the mine tailings was examined mineralogically and chemically. Cassiterite, being non-flotable or nearly so, would not be recovered in any of the concentrates being produced at the mine and would therefore report in the tailings. These are at the present time being allowed to fill up a small lake and thus would be available for re-treatment if the amount of tin in them should prove to be economically recoverable.

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[1] Subsequently the writer was informed by ing. Henning Fangel, of Bleikvassli Gruber A/S, that cassiterite had been previously detected during metallurgical experiments with the Bleikvassli ore in the laboratories of American Cyanamid.

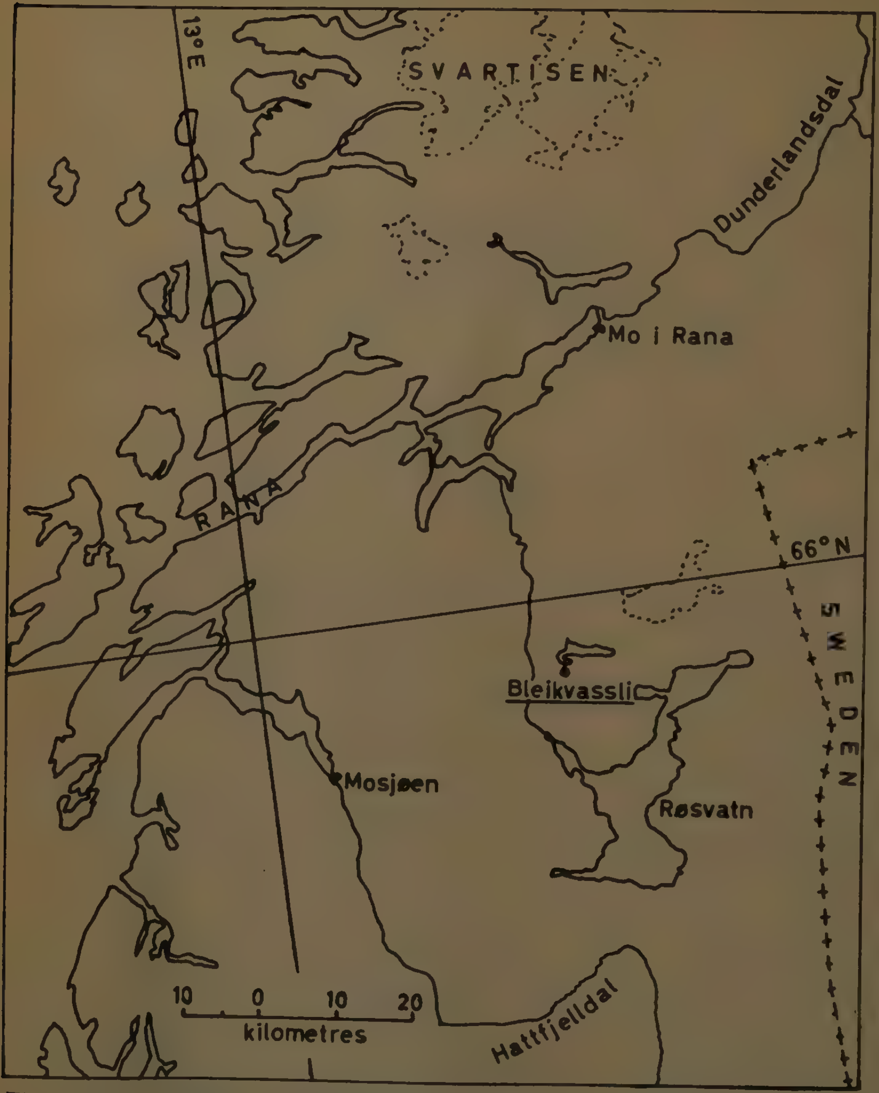


Fig. 1. Map of part of Nordland county, Norway, showing the location of Bleikvassli mine.

Apart from the economic possibilities, the presence of cassiterite in the Bleikvassli ore is of considerable scientific interest. Cassiterite is, on the whole, a rather rare mineral in Scandinavia. In Norway it has only been reported from one other locality, Tørdal in Telemark, where cassiterite occurs together with cleavelandite, quartz and lepidolite in a granite pegmatite (OFTEDAL, 1942). MAGNUSSON (1953) mentions the occurence of cassiterite in granite pegmatites, including lithium-rich types, at several localities in Sweden, while LANDERGREN (1943) reports the possible presence of the mineral in iron ore at Grängesberg.

On a world-wide scale the presence of cassiterite in pyritic lead-zinc sulphide ores is not at all common. Perhaps the most well-known example of the association is the ore at the Sullivan mine, Kimberley, British Columbia (PENTLAND, 1943). Here cassiterite is recovered as a by-product from an ore with an average content of about 0.05 % Sn.

LEA and RANCOURT (1958) mention the presence of cassiterite in the pyritic lead-zinc-copper ores of the Brunswick Mining and Smelting Company in Gloucester County, New Brunswick, but give no details regarding its mode of occurrence.

General Geology.

The ore body at Bleikvassli is a series of interconnected and branching "plates" or lenses of solid sulphides lying concordantly between mica schists and gneisses, which form part of the Caledonian mountain chain. In the northern part of the mine a microcline-biotite-quartz gneiss forms the footwall. The ore has been opened up and worked along a strike length of about 400 metres, while the deepest exploration workings now extend to about 200 metres below the surface outcrop. The ore "plates" vary considerably in thickness up to a maximum of about 10 metres. Along the strike in both directions the plates thin out to mere stringers of sulphides some few centimetres thick. The general strike of the country rocks is roughly NE, while dips are to the west of the order of 50°—60°, locally steepening to vertical.

The ore-forming minerals are, in order of relative abundance, pyrite, sphalerite, galena, pyrrhotite and chalcopyrite. Molybdenite occurs as a very minor constituent in most of the ore (0.0028 to 0.0094 % MoS_2 in 11 samples) and other, as yet unidentified, sulphides have been seen in polished section in even smaller quantities. Some of these latter may prove to be tin-bearing minerals, but they seem to be quantitatively unimportant.

Grains of scheelite ($CaWO_4$) were identified by means of x-ray diffraction patterns in separated fractions of the ore. They were quite rare, and no scheelite has been observed in thin section. No wolfram could be determined spectrographically in the Bleikvassli ore samples (limit of detection 0.005 %).

The ore may be divided into two main types, on the basis of mineralogy and texture. The by far the most abundant type consists of granular, sub- to euhedral pyrite with a grain size of the order of ½ to 2 mm, interstitial to which are variable quantities of sphalerite, galena, pyrrhotite and chalcopyrite as well as gangue (non-sulphide) minerals. The pyrrhotite content of this main ore type is usually below 5 per cent and only exceptionally does it rise to over 10 per cent.

The other type of ore, which is very subordinate quantitatively, is almost or wholly lacking in pyrite, the place of which has been taken by pyrrhotite. The other minerals seem to have the same general ranges of abundance. The texture of this type of ore is very much finer grained than that of the pyritic type. The texture is also very irregular and the included gangue fragments show evidence of strong deformation. The pyrrhotite rich ore occurs in part of one ore "plate" in the central part of the mine and as strips along the hanging or foot walls of the "normal" ore in several different parts of the workings. This ore type may be primary or it may have resulted from the metamorphism of the pyritic type. It is hoped that the study of the Bleikvassli ore now in progress will enable this problem to be solved.

Cassiterite in the ore.

The study of the cassiterite is made difficult by its scarcity (average 0.04 % SnO_2 in 38 ore samples) and by the small grain size of the mineral. So far none has been recognised in hand specimen, even with the aid of a binocular microscope. In crushed and separated fractions of the ore cassiterite can be seen as rounded to subhedral grains, often showing poorly developed crystal faces (Fig. 2). The colour ranges from nearly colourless to dark brown and often it shows distinct variations within an individual grain.

The mode of occurrence of the cassiterite in the ore is best studied by means of thin sections. The high refractive indices, high birefringence and the usually irregular colour zoning make it normally easy

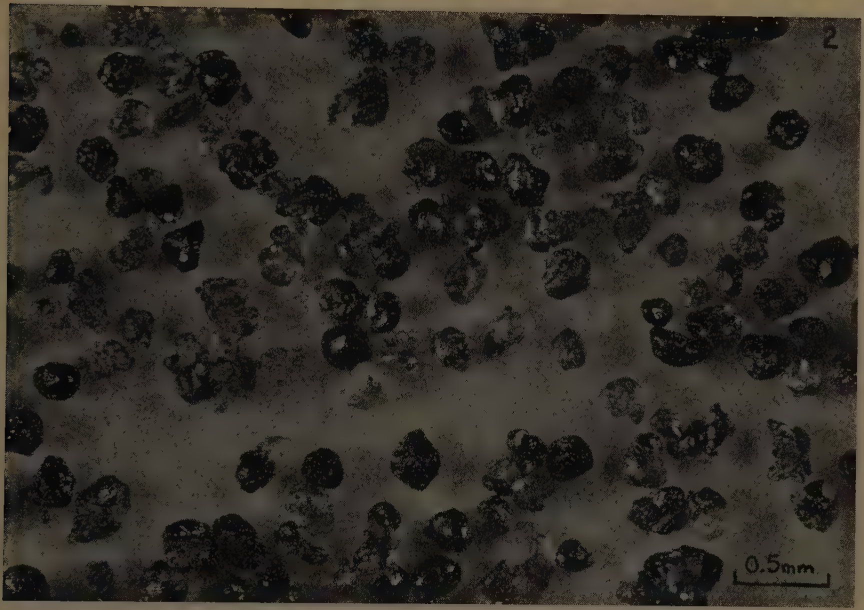
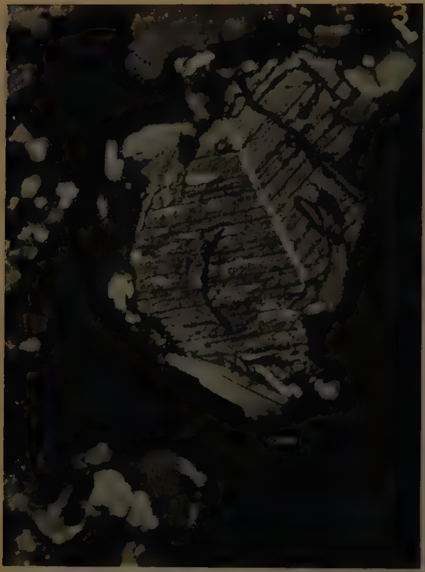


Fig. 2. Cassiterite grains separated from a crushed sample of the Bleikvassli ore.

to detect. Most thin sections of the massive sulphide ore contain at least two or three grains, in many it is much more abundant.

The maximum dimensions of fifty grains of cassiterite measured in thin sections ranged from 0.03 to 0.50 mm, with an average of 0.20 mm.

The grains show mainly subhedral to irregular cross sections with a greater tendency towards euhedral forms where they occur in patches of the quartz-mica gangue. Knee shaped twins were observed in a few instances, e.g. Fig. 3. A few other grains show short prismatic forms, but the majority tend to be equidimensional and rounded in outline. (Fig. 4). The cassiterite shows a very high relief and may be evenly colourless, or may show irregular streaks or patches of a light brown colour, normally dichroic. The coloured patches are often very indistinct and fade gradually into the colourless parts of the grains. The most common form of colouration is an indefinite annular ring with a colourless centre and rim; some few grains show a zonal colouration.



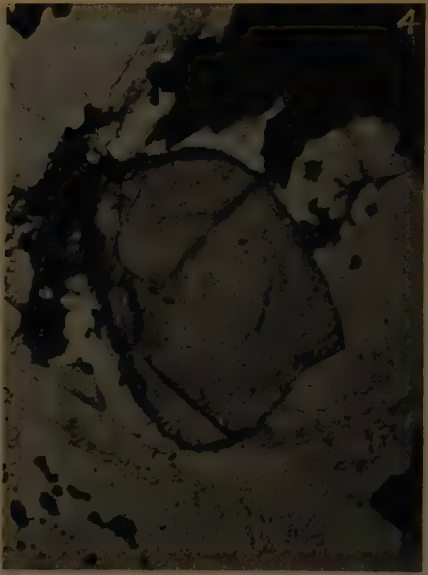


Fig. 3. Twinned grain of casiterite surrounded by sulphides, (black) mica and quartz. Crossed nicols. x130.

Fig. 4. Rounded grain of cassiterite in groundmass of quartz and sulphides. Ordinary light. x130.

The cassiterite is associated with all the main minerals in the ore, but statistically the majority of the grains occur in the quartz-mica gangue. They usually occur in an area of anhedral quartz mosaic and in most cases it is very striking that the grain size of the cassiterite is several times larger than the grain size of the quartz enclosing it.

Less often the grains of cassiterite occur isolated within the much larger grains of sulphide minerals, especially within idiomorphic pyrite grains.

Textural relations.

The full interpretation of the textures of the Bleikvassli ore is yet to be made. It is not yet clear whether they represent a paragenetical sequence of deposition or a crystalloblastic series resulting from metamorphism. The following remarks concern the apparent crystallisation relations of the cassiterite with respect to the other minerals without implying anything regarding the mode, or order, of introduction of the metallic components of the ore.

There is little or no evidence indicating a marked time difference of crystallisation between the cassiterite and the quartz and mica of the gangue of the ore. On the other hand there are indications that the main sulphides crystallised somewhat later than the gangue and the cassiterite. As far as the latter mineral is concerned this evidence consists mainly of fragments and irregular grains of the cassiterite set in grains and crystals of sulphides in a manner suggesting that the latter have surrounded and partly replaced the former. In one crystal of pyrite were seen three fragments of cassiterite in close proximity to each other, which were probably originally parts of a single grain. Cassiterite also occurs in small patches of the quartz-mica gangue which are clearly replacement residuals. In extreme cases of this type the cassiterite, with one or two attached quartz grains or mica flakes, occurs in the middle of a homogeneous mass of sulphides.

In addition a large grain of cassiterite was seen showing a prominent irregular fracture in which was deposited a thin veinlet of opaque sulphide.

Little direct evidence is at hand regarding the age relationship between the cassiterite and the molybdenite. Polished section work indicates that the molybdenite may have crystallised earlier than the major sulphides. Since scheelite has not yet been identified in thin section, nothing can be said of its place in the mineral paragenesis. However, it seems not unreasonable that the cassiterite, molybdenite and scheelite may be roughly of the same, somewhat early, age of crystallisation. There is, however, nothing to suggest that the metallic constituents of the ore were *introduced* at different stages. It seems most probable that they were all introduced simultaneously, but that some minerals crystallised before the others.

Discussion.

Pentland (op. cit. p. 20) mentions that in the Sullivan ore chalcopyrite, present in small amounts, may be taken as an indicator of tin values. Also pyrrhotite is more closely associated with the cassiterite than are the other common ore minerals. In the Bleikvassli ore no sympathetic relationship has so far been observed between the amount of tin and any other element or any mineral. (However, available analyses seem to indicate that there is a slight tendency towards a lower tin content in the pyrrhotite-rich type of ore described above). In addition no systematic variation in the cassiterite content has been observed along the strike or down the dip. There is however, a general tendency for the SnO_2 content to be higher in the wider parts of the ore. In samples taken across the ore body there is a tendency for the tin mineral to be concentrated towards the hanging-wall. This tendency seems to be more strongly pronounced where the sulphides occur in bands, separated by intervening, concordant, bands of schist. The study of the chemistry of the Bleikvassli ore is proceeding and a fuller report on the distribution of the tin values will be prepared.

The ore body at Bleikvassli is one of the large class of concordant sulphide bodies occurring in the Caledonian metallogenetic province in Norway. Normally the minerals pyrite, chalcopyrite, sphalerite, in very variable proportions, are typical for these ore bodies. However in certain sub-provinces, especially in southern Nordland and in the Ofoten district, galena makes its appearance, sometimes with a corresponding diminution in the content of chalcopyrite. The Bleikvassli ore belongs to this lead-enriched type, as do the ores at the Mofjell mine, Mo i Rana, and at several other, at present unworked, deposits.

It is not yet known how many more, if any, of these latter contain cassiterite. However, the scientific and possible economic interest attaching to the problem seems to warrant an extensive investigation of the mineralogy and geochemistry of the sulphide ores, and possibly also the granites, of the northern Caledonides as a whole, in order to determine whether the occurrence at Bleikvassli is of only restricted mineralogical interest or whether there is a widespread tin mineralization in the region.

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Manuscript received February 8, 1960.

Printed December 1960.

NORSK GEOLOGISK TIDSSKRIFT

THE MIDDLE ORDOVICIAN OF THE OSLO REGION, NORWAY

13. Trilobites of the family Asaphidae

By

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With 14 plates and 5 figures in text.

Abstract. More than 20 asaphid trilobite forms are described from the Middle Ordovician of the Oslo region. New are: *Ogygiocaris striolata, O. striolata corrugata, O. sarsi regina, O. sarsi delicata, Asaphus* (*Neoasaphus*) *heintzi, Ogmasaphus jaanussoni, O. kiaeri, O. stoermeri,* and *O. multistriatus.*

Ontogenetic stages of *Ogygiocaris sarsi* show that the pygidium becomes relatively narrower during growth, the pygidial axis becomes relatively wider and shorter, and the relative width of the doublure increases both in the pygidium and in the cephalon.

Certain glabellar features in *Ogygiocaris* suggest the presence of three preoral segments, A_1, pnt, and X, which all three seem to take part in the formation of the eye lobe.

The deformation of fossils is discussed and the term *L-form* suggested for elongated and/or narrowed forms, *W-form* for shortened and/or widened forms, and *O-form* for specimens preserving the original length/width proportion.

Two new descriptive terms are introduced, *paradoublural line* for a line on the dorsal test directly above and conformable with the inner margin of the doublure, and *band furrow* for the furrow separating the posterior band of the occipital and axial rings from their main part. The term "longitudinal" (long.) is preferred over "exsagittal" (exsag.) and/or "sagittal" (sag.) in relation to directions of measurements.

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Aknowledgements.

I wish to acknowledge my indebtness to Professor A. Heinz (Palaeontological Museum of the University of Oslo) and Professor L. Størmer (Palaeontological Department of the Geological Institute of the University of Oslo) for facilitating my study of the Middle Ordovician asaphids of the Oslo region, and to the latter also for having proposed that I undertook this study.

I am also grateful to Dr. V. Jaanusson (Palaeontological Institute of the University of Uppsala) and Dr. N. Spjeldnæs (Palaeontological Museum of the University of Oslo) for the discussion of certain problems.

For the loan of material I am greatly indebted to Professor Chr. Poulsen (Mineralogical Museum of the University of Copenhagen), Professor G. Regnéll (Palaeontological Institute of the University of Lund), Professor E. Stensiö (Palaeozoological Department of the Swedish Museum of Natural History), and Professor P. Thorslund (Palaeontological Institute of the University of Uppsala).

I have great pleasure in thanking Miss B. Mauritz for taking the photographs and Miss I. Lowzow for help with the drawings. The manuscript has kindly been read by Dr. R. D. Morton.

Introduction.

The present paper appears as no. 13 in a series dealing with the Middle Ordovician stratigraphy and fossils of the Oslo region. A team work on this subject was initiated by Professor Leif Størmer in 1950, and is supported by grants from the Norwegian Research Council for Science and Humanities.

The term Middle Ordovician is taken in the sense defined by STØRMER (1953), *i.e.* from and including the Llanvirnian zone of *Didymograptus bifidus* to and including the Caradocian zone of *Dicranograptus clingani.*

As proposed by STØRMER (1953, p. 51; map p. 53), the Cambro-Silurian of the Oslo region is divided into several districts, namely the southern districts Skien—Langesund (previously referred to as Langesund—Gjerpen), Eiker—Sandsvær, and Holmestrand; the central districts Oslo—Asker, Modum, Ringerike, and Hadeland; and the northern (or Mjøsa) districts Toten, Feiring, Hamar—Nes, and Ringsaker. Some of the districts are further divided into two or more areas, thus the Oslo—Asker district comprises from east to west the Oslo, Bærum, and Asker area.

The first description of a fossil species based on Norwegian material is that of a Middle Ordovician asaphid from the Oslo region, namely *Trilobus dilatatus* (now *Ogygiocaris dilatata*) described by BRÜNNICH in 1781.

Since then, only a few asaphids have been described from the Middle Ordovician of Norway. ANGELIN (1878) erected two subspecies of *Ogygiocaris dilatata*, which were named *sarsi* and *stroemi*. More recently, JAANUSSON (1953) has given descriptions or redescriptions, partly based on material from the Oslo region, of some Middle Ordovician Scandinavian asaphids, *i.e. Pseudoasaphus limatus* JAANUSSON, 1953, *Pseudomegalapsis patagiata* (TÖRNQUIST, 1884), and *P. formosa* (TÖRNQUIST, 1884).

Several species described in other countries have so far merely been recorded from the Middle Ordovician of the Oslo region, *e.g.* by BRØGGER from the Skien—Langesund district (1884) and the Oslo area (1887), by HOLTEDAHL (1909) from the Mjøsa district, and by STØRMER (1953) from the whole of the Oslo region.

In the present paper the Middle Ordovician asaphids of the Oslo region are treated monographically. Unfortunately most of the material consists of detached parts of the shield, whereas complete dorsal shields are rare and have not been found in several of the forms. For this reason, and because the preservation is not always too good, there are numerous specimens in the collections which I have not been able to determine, or at the best have only been able to determine with doubt. Some of these specimens suggest that there are more species present than described here. Most probably more species will be recognized when all the districts of the Oslo region have been more thoroughly investigated, and the geographical distribution of the known species may prove to be more extensive than recorded here. It is regrettable that stratigraphical data are inadequate or even missing for many specimens in the collections.

Asaphids from the "transition beds" between the Lower Ordovician Orthoceros limestone and the Middle Ordovician Ogygiocaris series have not been included here, since the detailed stratigraphy of these beds has not been fully worked out, and because they may be of

Lower rather than Middle Ordovician age. *Megistaspis* species are rather common in these transition beds. A dorsal shield (P.M.O. no. 72127) from Hornsodden (not Hovodden as previously stated) at Randsfjord, Hadeland, was assigned to *Asaphus* (*Neoasaphus*) *bottnicus* JAANUSSON, 1953 by JAANUSSON (1953a, p. 498) and was mentioned under this name by STØRMER (1953, p. 89). Dr. V. JAANUSSON has kindly informed me (1959) that it actually belongs to an undescribed species, which, however, resembles the somewhat later species *A.* (*N.*) *bottnicus*[1]. The dorsal shield from Hornsodden was collected 10.6 m above the compact Endoceras limestone, in a sequence of shale and limestone lenses which also yield *Megistaspis* species and thus apparently belong to the transition beds.

The following abbreviations are used in connection with catalogue numbers:

P.M.O. = Paleontologisk Museum, University of Oslo, Norway.
P.I.L. = Paleontologiska Institutionen, University of Lund, Sweden.
P.I.U. = Paleontologiska Institutionen, University of Uppsala, Sweden.
RM. = Palaeozoologiska avdelningen, Naturhistoriska Riksmuseet (Palaeozoological Department, Swedish Museum of Natural History), Stockholm, Sweden.
S.G.U. = Sveriges geologiska undersökning (Geological Survey of Sweden), Stockholm, Sweden.

Remarks on the deformation of fossils.

Just as the enclosing rock, fossils can be deformed by tectonic action. This naturally impedes the interpretation of the original appearance of the fossil. When a fossil is obliquely (asymmetrically) distorted, the distortion is readily recognized as such. More dangerous are the symmetrical distortions, which may be hard to detect. In respect to the orientation of bilaterally symmetrical fossils (like trilobites), one may distinguish between three main types of symmetrical distortion. The one is dorso-ventral compression (flattening). A slight dorso-ventral compression can be difficult to ascertain. Stronger flattening is usually recognized as such, *e.g.* in fossils lying parallel to the bedding planes in shales. Another type of symmetrical distortion is present where length is enlarged in relation to width, either by a stretching along the longitudinal direction of the fossil or

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[1] (Cf. also JAANUSSON, 1960, p. 278, footnote 1.)

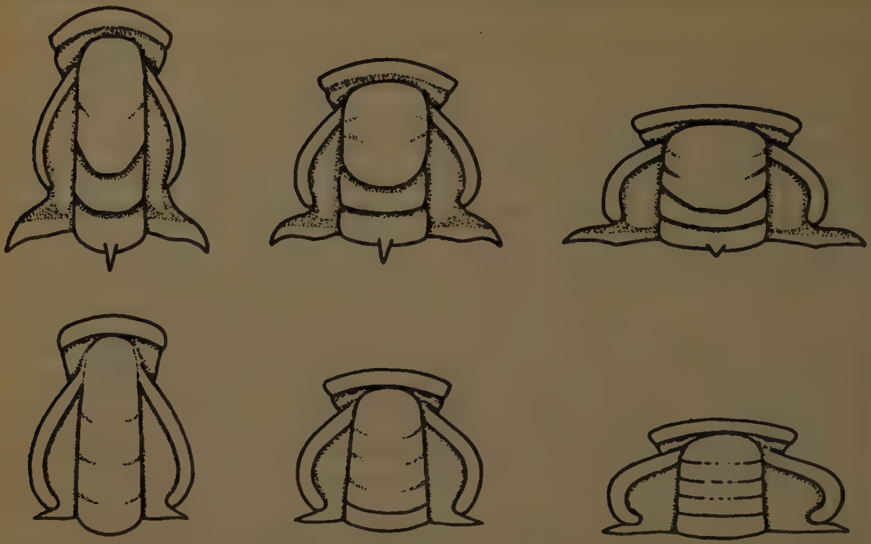

Fig. 1. L-, O-, and W-form of *Saukianda andalusiae* (above) and *Perrector perrectus* (below). The O-forms are restorations, the L- and W-forms are based on actual specimens. After HENNINGSMOEN (1957a).

by a compression normal to it, or both. The third type is present where the width is enlarged in relation to length, in a corresponding manner. The two latter types of symmetrically distorted fossils may be called *L-forms* ("long forms") and *W-forms* ("wide forms"), respectively, as suggested in an earlier paper (HENNINGSMOEN, 1957a, p. 253). Fossils with original length/width proportion may be called O-*forms*. L-, W-, and O-forms may of course be dorso-ventrally flattened.

Palaeontology is rich in examples where L-forms and W-forms of the same species have been taken as showing the original appearance of the fossil, and have been described under different names (cf. HENNINGSMOEN, 1957a). Apparently BARRANDE's "forme longue" and "forme large" of trilobite species merely represent forms differing in their type of deformation, namely L-forms and W-forms, respectively (cf. KIELAN, 1960, p. 41). In some cases O-forms and L-forms or O-forms and W-forms of the same species have been given different names. Dorso-ventrally flattened fossils have less commonly been believed to represent the original appearence.

When describing or comparing fossils it is important to find out whether they are symmetrically distorted, and especially be on guard for the treacherous L-forms and W-forms. One should be specially cautious in establishing names for forms differing from each other only in length/width proportion. It should also be remembered that other characters than this proportion may differ in L-forms and W-forms of the same species (cf. text fig. 1). Thus ridges normal to the direction of streching may become much less pronounced or even erased, whereas ridges and furrows normal to the direction of compression may become accentuated, and may even appear in places where they were not developed in O-forms. Furthermore, all angles will be changed in L-forms and W-forms, except right angles with one side parallel to the streching or compression. Similarly, the convexity of curves and surface will change.

Symmetrical distortion in a fossil may be indicated by the deformation of the rock and also by the associated fossils. The presence of obliquely distorted fossils is important, since they betray the deformation, and what appear to be O-forms probably are L-forms or W-forms. Furthermore, there is good reason for suspecting symmetrical distortion when similar forms oriented normal to each other on a bedding plane have different length/width proportions. A good example of this is shown by the two pygidia of *Ogygiocaris sarsi sarsi* in pl. 4, fig. 5. It may be mentioned that collectors sometimes tend to collect L-forms and W-forms rather than obliquely distorted specimens, since they look undistorted.

When a single L-form or single W-form is present, it is difficult to establish the original length/width proportion of the fossil. When both L-forms and W-forms are present, the original proportion can be calculated in some cases.

When it can be assumed that an L-form and a W-form had the same length/width proportion (P) before the deformation, and that the degree of deformation is the same in both, we have:

$$P = \frac{L'}{W'}\frac{X}{Y} \text{ and } P = \frac{L''}{W''}\frac{Y}{X}$$

Where L' and W' are the length and width of the L-form, L'' and W'' the length and width of the W-form, and X and Y denote the lengthening (or shortening) factors.

From this we have that:

$$P = \sqrt{\frac{L'}{W'} \frac{L''}{W''}}$$

To be able to assume that the degree of deformation is the same when only one L-form and one W-form are present, they should be in close proximity in the rock (as in the example mentioned above), since the deformation of the rock (and thus of the fossils) may vary over short distances. When a large number of L-forms and W-forms are present, the most extreme L-forms and the most extreme W-forms may be assumed to have the same degree of deformation. Since the length/width proportion may vary during ontogeny, the L-form and W-form used for calculating P should be chosen among specimens which may assumed to have had about the same original size.

Terminology.

On the whole I follow the terminology suggested in volume *O* of the Treatise on Invertebrate Paleontology, except that the term *glabella* is used in its original sense, *i.e.* including the occipital ring. Furthermore the symbols *S1*, *S2*, etc. and *L1*, *L2*, etc. are used for the glabeller furrows and lobes, repectively, counted from the rear (cf. JAANUSSON, 1956; HENNINGSMOEN, 1957). The terms ***paradoublural line*** and ***band furrow*** are new. The paradoublural line is a line on the dorsal test and lies directly above the inner margin of the doublure, with which it is conformable. It may be developed as a furrow, a more or less step-like flexure, or as a faint ridge. When present, it is usually better developed in the free cheeks (text fig. 5) and pygidium (pl. 2, fig. 6). The occipital ring is in some cases divided transversly by a forwards more or less convex furrow into the main part of the ring and a posterior band, widest in the median line. This band has been termed the «posterior band of the occipital ring" in the Treatise on Invertebrate Paleontology. Since the thoracic rings may show the same features, the term ***posterior band*** may be used for these rings, too. The furrow separating the posterior band from the main part of the ring, I propose to call the ***band furrow***. Apparently it is located directly above the anterior margin of the articulating half ring of the succeeding axial ring. It was referred to as the transversal line by STØRMER (1942, text fig. 14) and as the curving furrow by HENNINGSMOEN (1957, text fig. 1).

Where it is not obvious in which direction length and width are measured, (*tr.*) is added for transverse measurements, which are taken along lines transverse to the whole dorsal shield, and (*long.*) is added for longitudinal measurements, whether taken along the median line (sagittal line of some authors) or along a line parallel to it on either side (exsagittal line of some authors, sagittal line of others.) The same procedure has recently been suggested by KIELAN (1960, p. 6).

Longitudinal measurements of thorax and pygidium do not include the parts hidden in an outstretched dorsal shield (*i.e.* articulating half ring), even in a detached pygidium for example. This is done to facilitate comparison of lengths of *e.g.* a detached pygidium and a pygidium in a complete dorsal shield.

Family Asaphidae BURMEISTER, 1843.

NOTES ON ONTOGENETIC VARIATION

JAANUSSON (1953, p. 390) has shown that in *Asaphus* (*Neoasaphus*) *lepidus* TÖRNQUIST, 1884 the increase of height of the eyes in relation to the length of the cephalon is distinctly positively allometric (k = 1.13), whereas the length of the eyes shows a negative allometry (k = 0.47) and the height of the visual surface of the eye is isometric. Furthermore he shows that in *A.* (*Neoasaphus*) *ludibundus* TÖRNQUIST, 1884 there is a distinct negative allometry in all three cases. This shows that the size of the eye in relation to that of the cephalon cannot be used as a characteristic without taking into account the ontogenetic stage.

As pointed out to me by Dr. V. JAANUSSON, the relative widths of the pygidial and thoracic axes increase widt growth in *A.* (*Neoasaphus*) *ludibundus*, as is also evident from his measurements (JAANUSSON, 1953, p. 405).

Due to the distortion, which may be greater or smaller but has affected most specimens, the present material does not lend itself readily to statistical investigations. However, ontogenetic stages of the pygidium of *Ogygiocaris sarsi* show that there is a very distinct increase in the length/width proportion of the pygidium, and a distinct increase of the relative width of the pygidial axis during growth (pl. 6, figs.

6—10, 12; pl. 5, figs. 1—2). Also the relative width of the doublure increases with size, both in the pygidium and in the cephalon (and apparently also in the thorax). Since the pygidial axis reaches as far back as the inner margin of the doublure, the relative length of the axis as a consequence decreases with growth.

Notes on some glabellar structures

The trilobite glabella (including the occipital ring) in many cases show traces of the segmentation. In several trilobites the occipital furrow (SO) and 4 glabellar furrows or pairs of furrows (S1—S4) are present, separating the occipital ring (LO), 4 glabellar lobes (L1—L4), and a frontal glabellar lobe (or anterior lobe). L0—L3 have been interpreted as representing the postoral segments; L4 and the frontal lobe the preoral segments (cf. *e.g.* Størmer, 1942, p. 123). L4 is usually regarded as the axial portion of the antenullar segment (A_1). Following Hupé (1953), two other segments may be distinguished in front of A_1 in some trilobites, namely the preantennular segment (pnt) and the segment X.

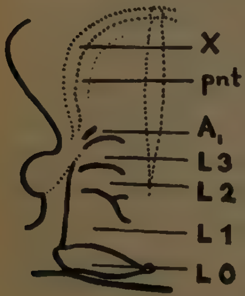

Fig. 2. Interpretation of segmentation of glabella of *Ogygiocaris.*

Better preserved specimens of *Ogygiocaris dilatata* and *O. sarsi* seem to show at least traces of all these segments. Thus the parafrontal band would correspond to the segment X, which is separated from the rest of the glabella by the shallow parafrontal furrow. In *O. sarsi* the parafrontal band (text fig. 5) is rather flat and confluent with the cheek areas, whereas the part of the glabella inside the parafrontal furrow is rather convex and might be taken as the whole of the glabella. In *O. dilatata,* however, the parafrontal band is more clearly a part of the glabella. The preantennular segment (pnt) is delimited by the parafrontal furrow in front and at the sides by the short S4. In some specimens there is a very faint furrow inside and parallel to the parafrontal furrow, possibly representing the boundary between pnt and A_1 and apparently constituting a continuation of the short but more distinct S4 (text fig. 2).

It appears that segments A_1, pnt, and possibly X take part in the formation of the eye lobe in *Ogygiocaris*, as is also suggested by HUPÉ (1953) for some Cambrian trilobites.

The parafrontal band is visible in some other asaphids as well, *e.g.* in *Pseudobasilicus? brachyrhachis* (cf. JAANUSSON, 1953, pl. IX, fig. 1).

A pair of longitudinal furrows, or rather rows of impressions, one on each side of the median line (cf. p. 219) may possibly represent the places of attachment of a ligamentary suspensory (of the heart?) and may be compared with an unpaired, median line of impressions in *Nileus armadillo* DALMAN, described by MOBERG in 1902 (cf. also HUPÉ, 1953, and HARRINGTON in Treatise on Invertebrate Paleontology, p. O101). The area between the two furrows in *Ogygiocaris* is almost ridge-like in some specimens (even in such retaining the original convexity). Similar structures occur in several other asaphids, *e.g. Pseudoasaphus aciculatus* (cf. JAANUSSON, 1953, pl. IV, fig. 3) and *Ogmasaphus praetextus* (*l.c.*, pl. V, fig. 4). Some well preserved cranidia of *Ogygiocaris dilatata* and *O. sarsi* show patches with extremely fine furrows, probably representing areas of attachment.

SUBFAMILY OGYGIOCARIDINAE RAYMOND, 1937

Genus *Ogygiocaris* ANGELIN, 1854

Type species: — *Trilobus dilatatus* BRÜNNICH, 1781 (pending ICZN, cf. below).

Remarks on name: — The generic name *Ogygiocaris* was published by ANGELIN (1854, p. 92). Although he listed *Ogygia* BRONGN. as a synonym, it is not quite clear whether he regarded *Ogygiocaris* as a substitute name for the supposedly preoccupied generic name *Ogygia* BRONGNIART in BRONGNIART & DESMAREST (1822), or as a new generic name for a group of species including *i.a. Trilobus dilatatus* BRÜNNICH, 1781. It has been proposed to the ICZN to use its Plenary Powers to give a ruling that the latter is the case, and that the type species of *Ogygiocaris* is *Trilobus dilatatus* BRÜNNICH, 1781.

Delimitation of genus: — The dainty pygidia of *Ogygiocaris* are often sent in to the Palaeontological Museum in Oslo as "fossil butterflies". Actually the pygidium seems to be the most characteristic part of *Ogygiocaris*, as restricted below. All the Scandinavian species of *Ogygiocaris* have in common the unusual, distinctly wavy inner margin of the pygidial doublure and the similarly wavy paradoublural line on the dorsal test of the pygidium. I suggest to restrict the genus *Ogygiocaris* to those species which show these characteristics. This means that the genus *Ogygiocaris* apparently has not been recorded outside Scandinavia, except in drift boulders from Scandinavia in N. Germany. *Ogygiocaris araiorhachis*, described from the Arenigian of Argentina by HARRINGTON & LEANZA (1957, p. 157), does not seem to show these features and should consequently be excluded from the genus, with which, however, it probably is related. Much the same can be said about *Ogygiocaris? plana* and *O.? inflexicostata* described from the Arenigian of France by THORAL (1946). The specimen described by RICHTER & RICHTER (1937, p. 302) as *Ogygiocaris?* sp. and mentioned by them again in 1954 (p. 14) from the Caradocian in Germany is a 5 mm long larval form whose affinities are uncertain. *Ogygia dilatata plautini* and *O. dilatata panderi*, both erected by SCHMIDT (1904, pp. 59, 62), have previously been excluded from the Asaphidae. The former was assigned to *Stygina* by SKJESETH (1955, p. 14). The latter form was made the type of the genus *Homoglossa* by RAYMOND in 1912. This genus is now regarded as a synonym of the styginid genus *Bronteopsis*, to which also *Ogygia? concentrica* LINNARSSON, 1869 is now assigned (cf. THORSLUND, 1940, p. 139 and SKJESETH, 1955, p. 16). The form assigned to *Ogygiocaris concentrica* (LINNARSSON) by FUNKQUIST (1919, p. 10) has later been described by SKJESETH (1955, p. 17) as *Bronteopsis holtedahli*. The only undoubted members of *Ogygiocaris* appear to be those described below.

Stratigraphical range of species; — A single fragment of an *Ogygiocaris* pygidium has been reported from the transitional beds between the Endoceras limestone (3cγ) and the Ogygiocaris series (4aα) near Furnes Church in Nes, Hamar-Nes (cf. STØRMER, 1953, p. 102). In Eiker-Sandsvær *Ogygiocaris dilatata* appears in 4aα_1 and occurs also in 4aα_2 as well as in the upper part of the Ogygiocaris series and apparently in the basal beds of the overlying Ampyx limestone (4aβ) (cf. STØRMER, 1953, pp. 72—73). In a section through the Ogygiocaris series along the beach between Sjøstrand and Hagabukta in Asker (text fig. 3), *O. dilatata* occurs in a horizon of limestone lenses in 4aα_2, 5 m below a continuous, thin limestone bed which may be regarded as being the basal bed of 4aα_3. However, graptolites are few in this

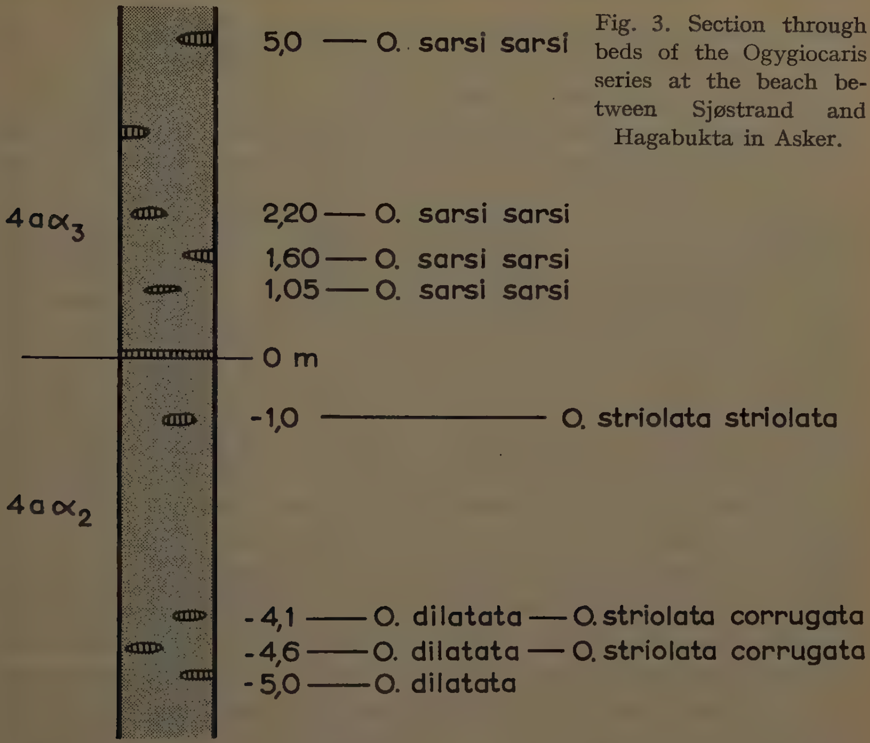
5,0 — O. sarsi sarsi
2,20 — O. sarsi sarsi
1,60 — O. sarsi sarsi
1,05 — O. sarsi sarsi
0 m
-1,0 — O. striolata striolata
-4,1 — O. dilatata — O. striolata corrugata
-4,6 — O. dilatata — O. striolata corrugata
-5,0 — O. dilatata
4aα3
4aα2

Fig. 3. Section through beds of the Ogygiocaris series at the beach between Sjøstrand and Hagabukta in Asker.

section, and the graptolite succession has not been worked out. Two other horizons of limestone lenses, 4.6 m and 4.1 m below this continuous limestone bed, contain *O. dilatata* associated with *O. striolata corrugata* n. subsp. and *Pseudomegalaspis patagiata*, whereas a limestone lens only 1 m below contained *O. striolata striolata* n. subsp. alone. The continuous limestone bed yielded no specimens of *Ogygiocaris*, but *O. sarsi sarsi* occurs in a horizon of limestone lenses 1.05 m above it and is very common up to about 5 m above the assumed base of 4aα_3 at this locality. Higher up the section is disturbed by faults. A section through the same beds is exposed slightly further north, at the southern shore of the peninsula of Elnestangen. Here, *O. striolata corrugata* and *O. dilatata* have been found in loose limestone lenses from 4aα_2, and *O. striolata striolata* in a lens 1 m below the thin, continuous limestone bed which is regarded as the base of 4aα_3. This bed yielded *O. sarsi sarsi*, which is very common all through 4aα_3, here about 14 m thick. *O. dilatata* and *O. striolata corrugata* reoccured in a limestone lens, apparently in situ, 3.5 m above the base of 4aα_3. The section continues up through the beds with *Trinucleus bronni* (4aα_4) and the overlying Ampyx limestone (4aβ). A 9 cm thick cross-bedded arenaceous limestone is regarded as the basal bed of 4aα_4, which is about 12 m thick. *O. sarsi sarsi* was found 4 m above the base of 4aα_4 and fragments of *O. sarsi* occurred even higher up, but were not well enough preserved to allow a determination of the subspecies, except for a single cranidium of *O. sarsi delicata* n. subsp. Poorly preserved specimens of *O. sarsi* have been found in the lowermost beds of the Ampyx limestone at other localities. Whereas *O. dilatata* apparently ranges all through the Ogygiocaris series (4aα) in the Eiker-Sandsvær district, *O. sarsi* seems to be a vicarious form in the upper part of the series in the central and northern districts of the Oslo region (cf. STØRMER, 1953, p. 120), where the shale is darker. It has not been possible for me to determine the stratigraphical relationship between *O. sarsi sarsi*, *O. sarsi regina*, and *O. sarsi delicata*, but there are indications that the two latter appear later than *O. sarsi sarsi*. Besides the specimen of *sarsi delicata* mentioned above, this subspecies has been found in situ on Helgøya (Hamar-Nes) just below the horizon with small limestone nodules between the shale with *Ogygiocaris* and the overlying Cephalopod shale as well as in the Cephalopod shale itself, whereas *O sarsi sarsi* occurs further down. If we arrange the forms of *Ogygiocaris* according to the width of the doublure, *O. dilatata* has the widest doublure, and it becomes progressively narrower in *O. striolata*, *O. sarsi sarsi*, *O. sarsi regina*, and *O. sarsi delicata*. It is tempting to assume that they appeared in this order, and that narrowing of the doublure was connected with the adaption to the rather poorly ventilated conditions under which the darkest Ogygiocaris shales were deposited. *O. sarsi* has been found as far down as in 4aα_1, 150 cm above its base, in black shales in Oslo—Asker. Unfortunately the specimens are not well enough preserved to allow a determination of the subspecies. *O. sarsi lata* has only been found in the dark Ogygiocaris shale of Andersön in Jämtland, Sweden. It is possible that this shale is somewhat younger than the Ogygiocaris shales in Norway and that *Ogygiocaris* survived longer there than in the Oslo region.

Ogygiocaris dilatata (Brünnich, 1781)

Pl. 1, figs. 1–7; pl. 2, figs. 1–6; text. fig. 4.

1781 *Trilobus dilatatus* — Brünnich, p. 393. (Descr.)
1817 *Asaphus debuchianus* n. sp. — Brongniart in Desmarest. (Descr. based on material from Eiker, Norway.)
1822 *Asaphus debuchii* (pars) — Desmarest, p. 20. (Material from Eger = Eiker in Norway mentioned, not figured.)
1827 *Asaphus dilatatus* — Dalman, p. 272 (reprint, p. 87), pl. III, fig. 1. (Remarks on and short descr. and fig. of Brünnich's original.)
1835 *Asaphus dilatatus* Dalm. (pars) — Sars, p. 336. (Not the figures, which are of *O. sarsi*.)
1838 *Trilob[ites] dilatatus* Brün. (pars) — Boeck in Keilhau, p. 141. (Mentioned.)
1854 *Ogygiocaris dilatata*. Brünn. (pars) — Angelin, p. 92. (Descr. It has not been possible for me to find a copy of this paper with the original pl. XLII, only the revised pl. XLII of the 1878 Appendix. Consequently I cannot say whether figs. 2a–c in the original pl. XLII were of *O. dilatata* or *O. sarsi*.)
1878 *Ogygiocaris dilatata*. Brünnich, genuina — Angelin, p. 96, pl. XLII, fig. 2. (Diagn. Fig. of dorsal shield, apparently the specimen described by Brünnich.)
1878 *Ogygiocaris dilatata*. var. *Strømi*. Ang. — Angelin, p. 96 pl. XLII, fig. 2*. (Diagn. Fig. of dorsal shield without free cheeks.)
1886 *Ogygia dilatata*, Brünn., genuina — Brøgger, p. 54, pl. III, fig. 39. (Remarks, fig. of hypostome.)
1887 *Ogygia dilatata* Brünn. (pars) — Brøgger, pp. 16, 17. (Recorded. Most specimens belong to *O. sarsi*.)
1953 *Ogygiocaris dilatata* forma typica — Størmer, p. 120 e.a., pl. 1. (Remarks on distribution in Norway. Fig. of slab surface with one almost entire dorsal shield and parts of others.)

Type data: — Brünnich (1871) had several specimens at hand when he described this species, but based his description on a single dorsal shield. As lectotype I select an almost complete dorsal shield (pl. 1 fig. 1) preserved in the Mineralogical and Geological Museum of the University of Copenhagen, Denmark. The accompanying label does not state that it is the specimen on which Brünnich based his description, but this can hardly be doubted. Its dimensions agree with those given be Brünnich, and an old plaster cast of the specimen, preserved in the Department of Paleaozoology of the Swedish Museum of Natural History, Stockholm, Sweden, bears an inscription on the reverse stating that the original is from Fossum Iron Works in Norway and belongs to Mr. Spengler in Copenhagen, just as stated by BRÜNNICH. DALMAN's rough drawing (1872, pl. 3, fig. 1) of *Asaphus dilatatus* apparently is based on the same specimen. Thus his drawing shows only 7 thoracic segments, which can readily be explained since the 8th. thoracic segment of the lectotype is telescoped over the slightly displaced pygidium, and is partly broken away.

The lectotype occurs in a hard, slightly (contact) metamorphosed dark shale (no doubt from the Ogygiocaris series) in the vicinity of Fossum in the Skien area of the Skien—Langesund district. The lectotype appears to be somewhat flattened. It is 10.5 cm long at the axial line and has maximum width of 8.4 cm.

Diagnosis: — A species of *Ogygiocaris* with the following characteristics: Pygidial margin with distinct posterior incurvation. Dorsal surface of pygidium with relatively openly spaced terrace lines. Pygidial doublure with openly spaced terrace lines and about half as wide as pleural regions in front. Cephalic doublure more than 4/5 as wide as distance from eye to cephalic margin.

Description: — Exoskeleton moderately convex, isopyguous, and with subelliptical outline. About 1.3 times as long as wide.

Cephalon subsemicircular, with genal spines, with isoteliform type of facial sutures, and with median suture across the doublure.

Cranidium with dominating, moderately convex glabella and rather flat cheek areas. Glabella (including occipital ring) about 1.4 times as long as wide, with slightly key-hole-shaped outline, and well defined laterally by dorsal furrows, but not along anterior lobe, where only a more or less distinct bend delimits the glabella. Occipital ring with distinct posterior band furrow. Each half of the occipital furrow deepest in the middle and slightly convex forwards, outer ends not reaching dorsal furrow except as very faint impressions, inner ends of the two halfs meeting the posterior band furrow medially, just behind small glabellar node, which has a rather posterior position. Glabellar furrows shallow and poorly defined. None of the furrows are connected across the glabella and they do not reach the dorsal furrow except as very faint depressions. S1 obliquely S-shaped. S2 slightly convex forwards, on the whole directed slightly backwards and inwards. S3 slightly convex forwards, on the whole transverse. S4 short, oblique forwards and inwards. There is a faint furrow slightly inside and parallel to the margin of the anterior lobe, separating a parafrontal band. Two

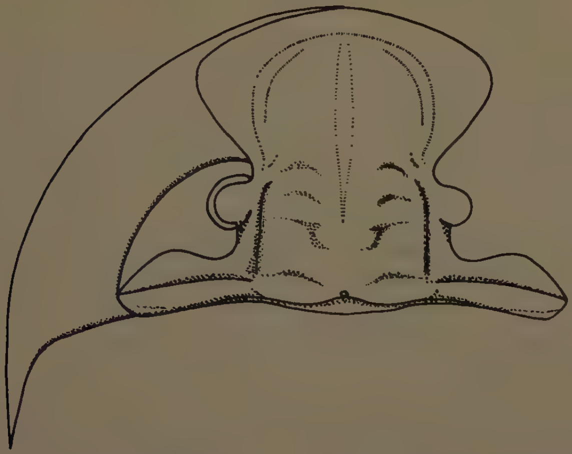

Fig. 4. Schematic reconstruction of cranidium and left free cheek of *Ogygiocaris dilatata.*

very faint furrows are situated close to each other on each side of the median line from the anterior end of the glabella to more than halfway on the glabella backwards. Especially in compressed specimens the area between these two longitudinal furrows may appear as a faint ridge. The furrows in question seem to be formed by a row of faint pits or rather short transverse depressions. Postocular cheek areas 3/4 as wide (tr.) as occipital ring. Postocular incurvation opposite L1. Interocular cheek areas very narrow. Preocular incurvation opposite S4. Palpebral lobes relatively small, semicircular. Preocular cheek areas up to about 1/2 as wide as postocular cheek areas. Frontal area relatively short. Anterior margin slightly pointed medially. Free cheeks wide, genal spines stout and confluent with margin. Distinct paradoublural line. Eyes holochroal. Cephalic doublure wide, more than 4/5 as wide as distance from eye to cephalic margin. Dorsal surface of cephalon with distinct terrace lines parallel to margin, on the free cheeks as far in as the paradoublural line, on the cranidium only close to the margin. Doublure with distinct terrace lines subparallel to margin. No panderian openings.

Hypostome subrectangular, only slightly longer than wide, and with bluntly pointed posterior margin. Border relatively narrow. Maculae and terrace lines distinct.

Thorax with 8 segments. Axial rings with posterior band furrow and a pair of poorly defined knob-like elevations in front of it. Pleurae less than twice as wide (tr.) as axial rings. Dorsal furrow distinct. Fulcrum located at about 2/5 the distance from dorsal furrow. Pleural furrows distinct, reaching 2/3 across pleurae from dorsal furrow. Outer 1/3 of pleurae with terrace lines subparallel to anterior and posterior margin of pleurae. Pleural tips falcate. Pleural doublures rather wide (tr.), with concave inner margin, but without any special panderian opening, and with terrace lines subparallel to outer margin of thorax.

Pygidium subsemielliptical in outline, with small but distinct incurvation posteriorly, and about 1.4 times as wide as long. Pleural regions about twice as wide as axis. Axis tapering backwards, not reaching posterior margin, and with slightly concave sides. Axis with 9 distinct axial rings and a posterior part with two indistinct axial rings and an endlobe. Pleural regions with 9 pleural furrows, the posterior one rather indistinct, all terminating well inside the margin. Pleural ribs faintly furrowed by the interpleural furrow in some specimens. The pleural ribs and furrows give the surface a corrugated appearance. Paradoublural line distinct and developed as a bend, along which the adaxial part of the surface is slightly depressed in relation to the abaxial part. Paradoublural line distinctly undulating, being closest to the axis on the ribs, and closest to the margin in the pleural furrows. Anteriorly the paradoublural line and the inner margin of the doublure are situated about halfway between axis and margin, and progressively nearer to axis rearwards, reaching axis slightly anterior to terminal lobe. Dorsal surface with relatively openly spaced and rather distinct and more or less transverse terrace lines on the border area outside the paradoublural line and in the pleural furrows inside this line as well as on the posterior half on the axial rings. Doublure wide, with undulating inner margin, and with relatively openly spaced terrace lines subparallel to outer margin, except near inner margin where they are progressively more undulating adaxially. Pygidium with somewhat flattened border.

Remarks: — Most of the material assigned to *Ogygiocaris dilatata* is from the Eiker—Sandsvær district. The lectotype is from the Skien area and its pygidium seems to differ from that of the common Eiker—Sandsvær form in being wider and shorter. However, the lectotype is rather flattened and may also be somewhat foreshortened. The pygidia from Eiker—Sandsvær have their convexity better preserved in most cases, but some are similar to the pygidium of the lectotype. For this reason I believe that the material from the two districts belong to the same form. Since ANGELIN's *Ogygiocaris dilatata* var. *Strömi* is similar to the Eiker—Sandsvær material, it becomes a synonym of *Ogygiocaris dilatata* (*dilatata*).

Dimensions: — The present material apparently includes only holaspid specimens. The smallest entire dorsal shield is 9.6 cm long, the largest 13.2 cm long. Fragments of larger specimens indicate that the dorsal shield may have attained a length of about 18 cm.

Occurrence: — *Ogygiocaris dilatata* occurs in the Ogygiocaris series (4aα) and possibly also in the lowermost beds of the overlying Ampyx limestone (4aβ) (cf. also p. 216). It is extremely common in certain horrizons in the Eiker-Sandsvær district and rather rare further north. OSLO—ASKER: Huk on Bygdøy, Hjortnestangen and Lille Frøen in Oslo; Engervik (4aα_2) and Elnestangen (4aα_2) in Asker; East of southern shore of Holsfjord, Lier. — SKIEN—LANGESUND: Fossum, Bø north of Skien; Brevik station; Skinnviktangen near Langesund. — EIKER—SANDSVÆR: Muggerudkleiva in Sandsvær; Krekling; Vestfossen. — MODUM. — RINGERIKE: Gomnes; Trøgstad in Norderhov.

Ogygiocaris striolata n. sp.

Name: — From Latin *striola*, diminutiv of *stria*, furrow, line, stripe, alluding to the extremely thin and densely spaced terrace lines on the outer surface.

Type data: — See under *O. striolata striolata* n. subsp.

Diagnosis: — An *Ogygiocaris* species with extremely fine and densely spaced terrace lines on the outer surface. Cephalon resembling that of *O. dilatata*. Posterior margin of pygidium without terminal incurvation, but may be terminally truncated. Paradoublural line in the anterior part of the pygidium closer to margin than to dorsal furrow.

Description, Dimensions, Occurrence: — See under the two subspecies.

Remarks: — Except for the characteristic ornamentation of fine terrace lines, *O. striolata* is morphologically intermediate between *O. dilatata* and *O. sarsi*. The cephalon of *O. striolata* is rather similar to that of *O. dilatata*, whereas the pygidium resembles more that of *O. sarsi*, both in the position of the paradoublural line and in not having a terminal incurvation. The pygidium of *O. striolata corrugata* resembles, however, the pygidium of *O. dilatata* in the roundness of the ribs, and has a truncated posterior margin, which may be regarded as intermediate between the incurved condition in *O. dilatata* and the predominantly evenly convex posterior margin in *O. sarsi*. The pleural ribs of *O. striolata striolata* are flattened, resembling more those of *O. sarsi*. In agreement with this, *O. striolata striolata* appears to be slightly younger than *O. striolata corrugata*.

Ogygiocaris striolata striolata n. subsp.

Pl. 3, figs. 4—10.

Type data: — Holotype is a pygidium (P.M.O. no. 72108 with counterpiece P.M.O. no. 72116) from the top of 4aα_2 between Sjøstrand and Hagabukta in Asker. Collected by G. Henningsmoen 1958.

Diagnosis: — An *Ogygiocaris* form with densely spaced terrace lines, both on the outer surface and on the doublure. Cephalon resembling that of *O. dilatata*. Pygidium resembling that of *O. sarsi*, with flattened pleural ribs and without terminal indentation.

Description: — Cranidium imperfectly known, apparently rather similar to that of *O. striolata corrugata* n. subsp. An incomplete free cheek shows that the paradoublural furrow is located about midway between the eye and the lateral border. Genal spine probably present. The hypostome resembles that of *O. sarsi*, but has finer terrace lines. Thorax unknown. Pygidium rather similar to that of *O. sarsi sarsi*, with evenly convex posterior margin, flattened pleural ribs, and paradoublural line markedly closer to lateral margin than to dorsal furrow in the anterior half of the pygidium. Densely spaced terrace lines, in a holaspid pygidium 4.1 cm long about 50 terrace lines pr. cm on the outer surface, and about 20 pr. cm on the doublure. Fine terrace lines are developed also on parts of the surface of the cranidium and free cheeks.

Dimensions: — Only a few specimens have been collected of this subspecies. The largest pygidium is about 7 cm wide (restored) and 4.1 cm long, indicating an overall length of the dorsal shield of about 10.5 cm.

Occurrence: — OSLO—ASKER: Between Sjøstrand and Hagabukta in Asker; Fornebu in Bærum. — RINGERIKE: Beach at Gomnes.

Horizon: — Cf. p. 215.

Ogygiocaris striolata corrugata n. subsp.

Pl. 3, figs. 1—3, 11.

Name: — From Latin *corrugata*, corrugated, alluding to the corrugated appearance of the pygidium.

Type data: — Holotype is an incomplete pygidium (P.M.O. no. 72134) from the top of 4aα_2 between Sjøstrand and Hagabukta in Asker. Collected by G. Henningsmoen 1958.

Diagnosis: — An *Ogygiocaris* form with fine and densely spaced terrace lines on the outer surface and rather openly spaced terrace lines on the doublure. Cephalon resembling that of *O. dilatata*. Pygidium with truncated posterior margin and with rather convex cross section of pleural ribs.

Description: — Cranidium resembling that of *O. dilatata*, but with very short (long.) preglabellar field and with smaller and narrower (tr.) preocular cheek areas. Free cheeks, hypostome, and thorax unknown. Pygidium resembling that of *O. striolata striolata* n. subsp. but with a more convex cross section of the pleural ribs, which are slightly inflated outside the paradoublural line, and with a truncated posterior margin. In a holaspid pygidium 3.9 cm long there are about 30 terrace lines pr. cm on the outer surface and about 20 pr. cm on the doublure. Also the cranidium is ornamented with densely spaced terrace lines on the outer surface.

Dimensions: — Only a few specimens have been collected. The largest pygidium is about 4 cm long, indicating an overall length of the dorsal shield of about 10.5 cm.

Occurrence: — OSLO—ASKER: Between Sjøstrand and Hagabukta, and at Elnestangen in Asker.

Horizon: — Cf. pp. 215, 216.

Ogygiocaris sarsi ANGELIN, 1878.

Remarks: — This species has hithero been regarded as a subspecies of *Ogygiocaris dilalata*. I have preferred to recognize *O. sarsi* as a separate species, partly because I have seen no transitional forms between it and *O. dilatata*, and partly because 4 subspecies can be distinguished within *O. sarsi*, all of which having certain features in common, which differ from those in *O. dilatata*.

Synonyms: — See under the different subspecies.

Type data: — See under *Ogygiocaris sarsi sarsi*.

Diagnosis: — An *Ogygiocaris* species without or with very faint posterior incurvation of the pygidial margin, with the paradoublural line anteriorly closer to the axis than to the margin of the pygidium, with the cephalic paradoublural line located at less than 4/5 the distance from margin to eye, and with relatively densely spaced terrace lines.

Description: — *Ogygiocaris sarsi* resembles on the whole *O. dilatata*, but differs in the following features. The glabella is narrower (about 1.7 times as long as wide) and more pointed in front. The postocular cheek areas are as wide as or wider (tr.) than the occipital ring, and the preocular cheek areas are also wider than in *O. dilatata*. The doublures are narrower in *O. sarsi*. The cephalic paradoublural line is closer to the margin in *O. sarsi*, and so is the pygidial paradoublural line, which anteriorly is located closer to the margin than to the axis. The pygidium has no or only a faint posterior incurvation in the margin. The terrace lines are on the whole more densely spaced in *O. sarsi* and less disconnected on the dorsal surface of the pygidium. Furthermore they usually cover the pleural ribs but are absent or poorly developed in the pleural furrows. The location (or absence) of the paradoublural line in the cephalon provides the best means of distinguishing the different subspecies of *O. sarsi*, whereas the pygidia are rather similar.

Dimensions: — See under the different subspecies. On the whole, *O. sarsi* is noticeably smaller than *O. dilatata*, although certain individuals may have reached a comparable size, and the subspecies *regina* may have attained an even larger size.

Remarks on ontogeny: — Small pygidia (of all subspecies) are relatively wider and shorter and have a narrower doublure than large pygidia, and their axes are relatively narrower. The axis reaches further back in small pygidia. The smallest pygidia have a rather evenly curved outer margin, whereas large pygidia tend to have a faintly triangular outline. During growth, the pygidia thus become relatively narrower and longer, the pygidial axis and the doublure become relatively wider, the axis becomes relatively shorter, and the outline of the pygidium becomes more triangular. In the cephalon, the glabellar furrows are better defined in small specimens.

Occurrence: — *Ogygiocaris sarsi* occurs in Norway in the Ogygiocaris series and in the lowermost beds of the overlying Ampyx limestone. NORWAY: Oslo region and adjacent districts to the northwest and northeast (for details, see under each subspecies.) — SWEDEN: Öland, Västergötland, Jämtland.

Ogygiocaris sarsi sarsi ANGELIN, 1878

Pl. 4, figs. 1—10; text fig. 5.

1835 *Asaphus dilatatus* DALM. (pars) — SARS, p. 336, pl. VIII, figs. 5a—b, pl. IX, fig. 11. (Descr., figs. of cephalon, pygidium, and hypostome.)
1838 *Trilob[ites] dilatatus* BRÜN. (pars) — BOECK in KEILHAU, p. 141. (Mentioned.)
1854 *Ogygiocaris dilatata*. BRÜNN. (pars) — ANGELIN, p. 92. (cf. synonymy list of *O. dilatata*.)
1878 *Ogygiocaris dilatata*. var. *Sarsi*. ANG. — ANGELIN, p. 96, pl. XLII, figs. 1, 1a—c. (Diagn. Figs. of dorsal shield, hypostome and side view of cephalon.)
1886 *Ogygia* (*Ogygiocaris*, ANG.) *dilatata*, BRÜNNICH, var. *Sarsi*. ANG. — BRØGGER, p. 53, pl. III, fig. 38. (Descr. and fig. of hypostome.)
1887 *Ogygia dilatata*, BRÜNN. (pars) — BRØGGER, p. 16, 17. (Recorded. Most specimens belong to *O. sarsi*.)
1898 *Ogygia dilatata*, var. *Sarsi* ANG. — BJØRLYKKE, p. 24, fig. on p. 25. (Mentioned. Reduced reproduction of ANGELIN's fig. of dorsal shield.)
1901 *Ogygia dilatata* var. *Sarsi* ANG. — LINDSTRÖM, p. 63, pl. V, figs. 27—28. (Descr. and figs. of hypostome.)
1940 *Ogygiocaris dilatata* (BRÜNNICH) — STØRMER, p. 125, text fig. 3; figs. 5a—b. (Mentioned. Reproduction of SARS' figs.)
1940 *Ogygiocaris dilatata* (BRÜNN.) — GRORUD, pp. 158—160. (Recorded.)
1953 *Ogygiocaris dilatata sarsi* (pars) — STØRMER, p. 12. (Remarks on distribution in Norway of *O. sarsi*. The fig. on pl. 2 is of *O. sarsi regina* n. subsp.)

Type data: — The specimen figured by ANGELIN (1878) has not been located. As neotype I select a specimen collected by M. SARS and believed to be the original of his drawing (P.M.O. no. 20287 and counterpiece no. 20288). If ANGELIN's drawing is a reconstruction, it may in part be based on this specimen. The neotype occurs in dark limestone from the Ogygiocaris series, no doubt from the Ogygiocaris shale s.s. (4aα_3), from Hjortnestangen in Oslo.

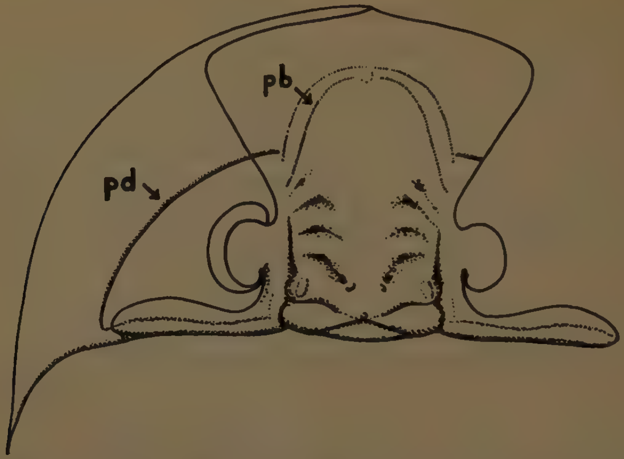

Fig. 5. Schematic reconstruction of cranidium and left free cheek of *Ogygiocaris sarsi sarsi*. pb = parafrontal band, pd = paradoublural line.

Diagnosis: — A subspecies of *Ogygiocaris sarsi* with the cephalic paradoublural line closer to eye than to margin and with frontal area longer (long.) than occipital ring.

Description: — The main differences from *Ogygiocaris dilatata* are pointed out under the description of *O. sarsi*. The paradoublural line on the cephalon is located at about 1/4 the distance from eye to margin, and is present also on the cranidium. The anterior margin is well pointed in front in most specimens. As in *O. dilatata*, a faint furrow is located parallel to and slightly inside the dorsal furrow in the anterior lobe, but the two furrows close to the median line of the glabella are not visible in *O. sarsi sarsi*. On the other hand, *O. sarsi sarsi* has in some specimens a small node-like elevation at the anteri-median point of the glabella, and the hypostome has a small antero-median notch in the median body. The deeper parts of the glabellar furrows are pit-like, especially in smaller specimens. The pits delimit a stem-like area behind the anterior lobe, the latter having an almost circular outline and being markedly more convex than the rest of the glabella. A slightly elongated elevation is present on each of the basal lobes, rather close to the dorsal furrow. The postocular cheek areas are about as wide (tr.) as the occipital ring and the preocular cheek areas about 2/3 as wide as the postocular ones. A faint postaxial ridge is discernible in some pygidia.

Dimensions: — No complete dorsal shields have been found of this subspecies. The largest pygidium present is 6.2 cm wide and 3.5 cm long, indicating an overall length of the dorsal shield of about 9 cm. The largest cranidium present is 5.6 cm wide (restored) and 3.3 cm long, indicating an overall length of about 10.5 cm. The smallest pygidium present is 1.0 cm wide and 0.5 cm long.

Occurrence: — *Ogygiocaris sarsi sarsi* occurs with certainty in $4a\alpha_3$ and $4a\alpha_4$, and *O. sarsi* (probably subspecies *sarsi*) is infrequently met with in $4a\alpha_1$ and $4a\alpha_2$ in the Oslo—Asker district. It is very common in $4a\alpha_3$ in the Oslo—Asker district.

Oslo—Asker: Hjortnestangen, Frogner Park, Maridalsveien 13, Dovregata, Lille Frøen, Huk on Bygdøy, Vekkopp on Bygdøy in Oslo; Stabekk and Fornebu in Bærum; Steilene; Djuptrekkodden, Eternittfabrikken, Elnestangen and between Sjøstrand and Hagabukta in Asker, as well as in other places where the Ogygiocaris shale crops out. — Skien—Langesund: Skinnvikbukta. — Eiker—Sandsvær: Råenkollen. — Hamar-Nes: Flakstadelva.

Ogygiocaris sarsi regina n. subsp.

Pl. 5, figs. 1—8; pl. 6, fig. 5.

1913 *Ogygiocaris dilatata* Brünn. var Sarsi Ang. (pars) — Hadding, p. 72, text fig. 23. (Descr. and fig. of large pygidium.)
1935 *Ogygiocaris lata* (Hadding) n. sp. (pars) — Thorslund in Thorslund & Asklund, p. 18, pl. 1, fig. 1. (Descr. and fig. of cranidium.)
1953 *Ogygiocaris dilatata sarsi* (pars) — Størmer, pl. 2. (Fig. of dorsal shield.)

Name: — The name *regina* (L., queen, princess) alludes to a nickname, "the Toten princess", which has been given to the holotype.

Type data: — The holotype is an entire dorsal shield (P.M.O. no. 72090) and its counterpiece (no. 72092), belonging to an old collection from the Ogygiocaris series in Toten.

Diagnosis: — A subspecies of *Ogygiocaris sarsi* with the paradoublural line located about midway between the eye and the margin of the cephalon, and with the frontal area about as long (long.) as the occipital ring.

Description: — Apart from the narrower cephalic doublure and the location of the paradoublural line on the cephalon, the subspecies *regina* is apparently rather similar to the nominal subspecies. Pygidia of *O. sarsi regina* n. subsp. (and of *O. sarsi delicata* n. subsp.) tend to have a more triangular outline than those of *O. sarsi sarsi*, especially in larger specimens. The holotype pygidium and some other pygidia of *O. sarsi regina* n. subsp. have a faint posterior incurvation of the margin, not observed in *O. sarsi sarsi*. It is not as distinct as the posterior incurvation in *O. dilatata*.

Dimensions: — The holotype is 6.8 cm long and 5.15 cm wide. Separate pygidia and fragments of cephala indicate that the species could become somewhat larger. Swedish material suggests a considerably larger size.

Notes on Swedish material: — Cranidia and other parts from different localities in Jämtland, Sweden, agree very well with the Norwegian form, except that some of the Swedish specimens represent considerably larger individuals. Of several large cranidia, the largest is 7.7 cm wide (restored) and 4.7 cm long, corresponding to an overall length of the dorsal shield of about 15 cm. Several large pygidia are also present, including the huge pygidium figured by HADDING (1913, text fig. 23) as *O. dilatata* var. *Sarsi*. It is 8.05 cm long, suggesting that the entire dorsal shield was more than 20 cm long. This is more than the greatest calculated length (18 cm) for *O. dilatata*, which generally is a larger form than the subspecies of *O. sarsi*.

Occurrence: — *Ogygiocaris sarsi regina* occurs in Norway in the Ogygiocaris series, exact horizon not known (uppermost part? Cf. p. 216).

OSLO—ASKER: Rådhuset in Oslo; Fornebu Air Field in Bærum; Slemmestad in Asker; Ildjernet. — MODUM: Melå. — HADELAND: Haugalandet; Hovstangen in Gran; North of Juv in Gran. — TOTEN: Dyste bridge. — HAMAR—NES: Hovindsholm on Helgøya. — SWEDEN: Andersön and Raftan in Jämtland.

Ogygiocaris sarsi delicata n. subsp.

Pl. 6, figs. 1—4, 6—12.

Name: — From Latin *delicata* (delicate, dainty), alluding to the narrow doublure which gives this subspecies a dainty appearance.

Type data: — Holotype (P.M.O. no. 36673) is a cranidium from

Helgøya (Hamar—Nes), preserved in dark limestone and collected by W. C. Brøgger in 1881. Exact horizon not known.

Diagnosis: — A subspecies of *Ogygiocaris sarsi* with a rather narrow doublure and with the paradoublural line of the cephalon closer to the margin than to the eyes. Frontal area somewhat shorter (long.) than occipital ring.

Description: — Apart from the differences mentioned in the diagnosis, this subspecies is rather similar to *O. sarsi sarsi*. The rather anterior position of the paradoublural line on the cranidium places it near the widest (tr.) part of the preocular cheek areas, and the line is thus relatively longer (tr.) than in the other subspecies.

Dimensions: — The few specimens referable to this subspecies are all rather small. The largest pygidium indicates an overall length of the dorsal shield of about 2.6 cm.

Remarks: — One might suspect that this subspecies is only a larval form of *e.g. O. sarsi regina*, especially as the relative width of the doublure increases with growth in *Ogygiocaris*. However, cranidia of *O. sarsi regina* show the typical position of the paradoublural line (and thus of the inner margin of the doublure) even when they are as small as or even smaller than cranidia of *O. sarsi delicata*. Neither do these two subspecies seem to occur together.

Occurrence: — *Ogygiocaris sarsi delicata* n. subsp. occurs apparently only in the uppermost part of the Ogygiocaris series (cf. p. 000) and in the Cephalopod shale in the northern districts.

Hadeland: South of Skiaker in Gran; Hovstangen in Gran. — Toten: Kolbo in N. Toten. — Hamar—Nes: Helskjær and Hovindsholm on Helgøya; Sterudstranda in Nes. — Ringsaker: Furnes Church.

Ogygiocaris sarsi lata Hadding, 1913

Pl. 5, fig. 9.

1913 *Ogygiocaris dilatata* Brünn, var *lata* n. var. — Hadding, p. 72, pl. VII, figs. 8, 9a—c. (Descr. and figs. of pygidium and free cheeks.)

1913 *Ogygiocaris dilatata* Brünn. var. *Sarsi* Ang. — Hadding, p. 70, pl. VII, figs. 1—7. (Descr. Figs. of cranidium, free cheeks, hypostome, thoracic segment, and pygidia. Not text fig. 23 = *O. sarsi regina*.)

1913 *Ogygiocaris dilatata* Brünn, var *Strömi* Ang. — Hadding, p. 72, pl. VII, fig. 10. (Remarks. Fig. of pygidium.)

1935 *Ogygiocaris lata* (HADDING) n. sp. (pars) — THORSLUND in THORSLUND & ASKLUND, p. 18. (Remarks. The descr. and fig. of cranidium are of *O. sarsi regina* n. subsp.)

Type data: — As lectotype I select the free cheek (P.I.L. no. LO 2530), figured by HADDING (1913, pl. VII, fig. 8). It is from the Ogygiocaris shale of Andersön in Jämtland, Sweden.

Diagnosis: — A subspecies of *Ogygiocaris sarsi* with no traces of the paradoublural line on the cranidium (only on the free cheeks) and with facial sutures more divergent in front of the eyes than in the other subspecies.

Descriptive remarks: — Besides the differences mentioned above, the glabella of this subspecies appears to be relatively wider than in the other subspecies. It might perhaps be regarded as a separate species, but its pygidium is very similar to that of the other subspecies of *O. sarsi*, except that the adult pygidia appear to have a slightly more semicircular outline.

Remarks: — In 1913 HADDING erected *Ogygiocaris dilatata* var. *lata* which was based on small free cheeks and pygidia from Andersön in Jämtland, Sweden. It was to differ from *O. dilatata* var. *Sarsi* (= *O. sarsi*) in being smaller, in having a relatively longer pygidial axis, and in having a relatively wider pygidium. However, this is just what is characteristic of small pygidia of *O. sarsi*. The free cheeks assigned to var. *lata* have very narrow doublure. This is true also of small free cheeks of *O. sarsi*. It therefore appears that var. *lata* was erected on larval forms of *O. sarsi*. The question is then of which subspecies. Besides var. *lata*, HADDING (1913) described *O. dilatata* var. *Sarsi* (= *O. sarsi*) and *O. dilatata* var. *Strömi* (= *O. dilatata*) from the Ogygiocaris shale of Andersön. The latter is determined on a couple of pygidia, which are of the *sarsi* type rather than the *dilatata* type, with relatively narrow doublure. They were assigned to var. *Strömi* (= *O. dilatata*) because of the posterior indentation. However, the indentation is more distinct in *O. dilatata*, whereas a faint indentation is known in some pygidia of *O. sarsi*. A huge pygidium, assigned by HADDING (1913) to var. *Sarsi*, seems to belong to *O. sarsi regina* n. subsp. which occurs on Andersön (cf. p. 228). The other specimens assigned by HADDING to var. *Sarsi* do not belong to any of the subspecies of *O. sarsi* described from Norway. Most probably the larval forms described as var. *lata* belong to this form rather than to *O. sarsi regina* n. subsp.

The originals of var. *lata* are unfortunately not associated with larger cranidia or free cheeks, but they seem to come from the same bed as this form, which is associated with larval parts of the shield similar to those described as var. *lata*. *O. sarsi regina* seems to occur in another, possibly lower level on Andersön. For the above reasons the material assigned to *O. dilatata* var. *Sarsi* by HADDING is believed to represent adult specimens of the subspecies *lata*.

In 1935 THORSLUND described a cranidium as in all probability belonging to HADDING's var. *lata* (which was given rank of species, *O. lata*). It came from the Ogygiocaris shale at Raftan in Jämtland and agreed with the pygidium of *lata* in having the same width/length proportion, *i.e.* 2 : 1. However, it came from a larger specimen than the parts assigned to *lata* by HADDING, and, as pointed out above (p. 211), the ratio changes with the size of the pygidium. The cranidium described by THORSLUND apparently belongs to the form described here as *O. sarsi regina*, but appears to be somewhat deformed (W-form), probably because it is embedded in its matrix at an angle to the bedding plane.

Material: — The largest cranidium examined is 2.6 cm long and 4.6 cm wide, indicating a total length of the dorsal shield of about 7.5 cm.

Occurrence: — Ogygiocaris shale, Andersön in Jämtland, Sweden.

SUBFAMILY ASAPHINAE BURMEISTER, 1843

Genus *Asaphus* BRONGNIART, 1822

Subgenus *Neoasaphus* JAANUSSON, 1953

Type species: — *Asaphus ludibundus* TÖRNQUIST, 1884.

Synonym: — *Trematophorus* BALAŠOVA, 1953.

Asaphus (*Neoasaphus*) *heintzi* n. sp.

Pl. 7, figs. 1—3.

Name: — The species is named in honour of Professor, Dr. Anatol Heintz, who collected most of the material of this species.

Type data: — The holotype is an almost complete, but somewhat distorted dorsal shield (P.M.O. no. 72073) from the Lower Chasmops shale (4b*a*) in a road cut in the road Oslo—Drammen (Drammensveien) near Gyssestad, Asker. Collected by A. Heintz, 1932.

Material: — Six more or less complete dorsal shields and several detached plates preserved in shale, all compressed and distorted.

Diagnosis: — A species of *Asaphus* (*Neoasaphus*) apparently without frontal area, genal corners apparently without spines, and preocular cheek areas moderately wide at anterolateral corners. Thorax with unusually wide axis as wide as or slightly wider than pleural regions; inner margin of pleural doublure oblique forward and inward, slightly sinuous. Pygidium twice as wide as long, axis in front about 4/3 as wide as pleural region. Doublure somewhat less than half as wide as pleural regions along anterior pleural furrow and with inner margin subparallel to pygidial margin.

Description: — The general features are seen in the illustrations.

Cephalon apparently without frontal area, as far as can be judged from the present specimens. Genal corners angular, apparently without spines. Posterior border of free cheek moderately convex. Preocular cheek areas about 1/4 as wide as glabella at rounded anterolateral corners. Eyes much closer to posterior than to anterior cephalic margin and longer (long.) than their distance from posterior cephalic margin. Postocular cheek areas about 2/3 as wide (tr.) as occipital ring. Doublure about half as wide as distance from eye to cephalic margin and with terrace lines subparallel to margin. Slit-like panderian opening. Hypostome unknown.

Thorax with axis as wide as or wider than pleural region. Fulcrum at about 2/3 of distance from dorsal furrow to lateral margin. Doublure with terrace lines and isolated panderian openings. Inner margin of pleural doublure oblique inwards and forwards, slightly sinuous (slightly concave).

Pygidium about twice as wide as long. Axis in front about 3/4 as wide as pleural region. Terrace lines lacking on outer surface of test, but this may be due to the state of preservation. Doublure somewhat less than half as wide as pleural region at anterior pleural furrow and with terrace lines subparallel to margins. Inner margin of doublure subparallel to pygidial margin, except posteriorly where it curves around the posterior tip of axis.

Dimensions: — The specimens are all rather distorted. The least distorted dorsal shield (P.M.O. no. 55696) is about 10.8 cm long and about 8 cm wide. Other specimens show that the species attained a somewhat larger size.

Affinities: — *Asaphus* (*Neoasaphus*) *heintzi* n. sp. resembles *A.* (*N.*) *ludibundus* and probably belongs to the group of *A.* (*N.*) *ludibundus*. It differs from all the other known members of this group in its very wide thoracic axis.

Occurrence: — *Asaphus* (*Neoasaphus*) *heintzi* n. sp. is known with certainty only from the Lower Chasmops shale (4b*α*).

OSLO—ASKER: Near Slependen in Asker (4b*α*); Sportsplassen on Bygdøy in Oslo (4b); ?Bjerkholmen near Fornebu in Bærum (horizon?).

Asaphus (*Neoasaphus*) *ludibundus* TÖRNQUIST, 1884

Pl. 8, figs. 1—5.

1884 *Asaphus ludibundus* n. sp. — TÖRNQUIST, p. 71, pl. III, figs. 4—5. (Descr., figs. of dorsal shield and cephalon.)
1884 *Asaphus acuminatus* NIEZK. (nicht BOECK) — BRØGGER, p. 260. (Recorded.)
1884 *Asaphus acuminatus* NIEZK. var. — BRØGGER, p. 261. (Recorded.)
1886 *Asaphus ludibundus* TÖRNQUIST — BRØGGER, p. 30, pl. I, fig. 7. (Descr. and fig. of hypostome.)
1887 *Ptychopyge* conf. *glabrata*, ANG. — BRØGGER, p. 19. (Recorded.)
1887 *Asaphus* conf. *acuminatus* NIEZKOWSKI — BRØGGER, p. 19. (Recorded.)
1953 *Asaphus* (*Neoasaphus*) *ludibundus* TÖRNQUIST, 1884 — JAANUSSON, p. 399, pl. I, figs. 1—12; pl. II, figs. 1—2; text figs. 3(5), 5(2), 6. (Detailed descr. Figs. of all parts of dorsal shield. List of synonymies. Recorded for the first time from Norway.)
1953 *Asaphus ludibundus* — STØRMER, p. 65. (Recorded.)

Type data: — Lectotype (selected by JAANUSSON, 1953) is a dorsal shield (P.I.L. no. LO 618 T) from the Ludibundus limestone in Kårgärde, Siljan area, Sweden.

Norwegian material: — Four more or less complete dorsal shields, numerous detached parts of the shield. Most of the specimens are preserved in limestone.

Remarks: — *Asaphus* (*Neoasaphus*) *ludibundus* differs from the other Middle Ordovician asaphids occurring in Norway in the following combination of characters: Dorsal surface rather smooth; thus the dorsal furrow is not very distinct, the axial rings in the pygidium are poorly defined, and the pleural ribs are only faintly developed in the pygidium. Genal corners more or less rounded, without spines. No frontal area. Glabella rather steep in front. Anterolateral corners of glabella rather well rounded. Preocular cheek areas moderately to rather narrow. Cephalic doublure channelled (as seen from above) and only slightly wider than distance from eye to outer margin. Pygidium tending towards a faintly triangular outline, rather evenly vaulted. Pygidial doublure somewhat less than half as wide as pleural region at anterior pleural furrow.

As observed by JAANUSSON (1953) several characters vary somewhat from specimen to specimen, *e.g.* the angle of the genal corners, the height of the glabella compared with that of the palpebral lobes, and the width of the preocular cheek areas. Furthermore the relative length and the height of the eyes decrease with growth, and the width of the thoracic axis increases. These variations are seen also in the Norwegian material, which on the whole agrees well with the Swedish specimens. However, on the whole the pleural regions of the pygidia are somewhat wider in relation to the axis in the Norwegian material (this may partly be due to flattening) and the fulcrum is placed slightly more distally in some specimens. Furthermore the palpebral lobes seem to be more tilted, at least in some of the Norwegian specimens.

Dimensions: — Some of the Norwegian specimens are larger than those described from Sweden. A dorsal shield has an overall length of about 10.9 cm and detached pygidia indicate a total length of the dorsal shield of at least 12 cm.

Occurrence: — *Asaphus* (*Neoasaphus*) *ludibundus* occurs in the Ampyx limestone (4aβ), the Lower Chasmops shale (4bα), and the Lower Chasmops limestone (4bβ). It is relatively common. A few specimens have been found in Coelosphaeridium beds (4bα?) at Toten.

OSLO—ASKER: Oslo (4b?); Huk on Bygdøy (4a?); Bygdøy (4bα); Rambergøya (4bβ and top of 4bα); Nakkholmen (4bβ); Western point of Ildjernet (top of 4aβ); Southern point of Persteilene (4b); Østøya (4bα-β); Gyssestad (4aβ?). — SKIEN—LANGESUND: Saltboden (4aβ). — RINGERIKE: Bratterud (4bα-β); Section Gomnes—Rud (4bα?). TOTEN: Sund (4bα?) — SWEDEN.

Asaphus (*Neoasaphus*) cf. *ludibundus* TÖRNQUIST, 1884

Pl. 8, fig. 6.

1909 *Asaphus* n. sp. — HOLTEDAHL, pp. 9, 29, 40. (Recorded.)

Remarks: — A complete but somewhat worn dorsal shield in a round limestone lens from the Cephalopod shale of the Mjøsa districts has the fulcrum placed much further out and has considerably wider (tr.) cheeks than *A.* (*N.*) *ludibundus*, with which it has many features in common. It is here referred to as *A.* (*N.*) cf. *ludibundus*. The specimen is 8.1 cm long.

Asaphus (*Neoasaphus?*) sp. A

Pl. 14, fig. 9.

Remarks: — Two pygidia, rather similar to each other, have been collected from the Encrinite limestone (4bδ) at Ås at Frierfjorden, Skien—Langesund. They have rather narrow pleural regions and a rather roundish outline.

Asaphus (*Neoasaphus?*) sp. B

Pl. 14, fig. 10.

Remarks: — A single asaphid pygidium has been collected from the Upper Chasmops limestone (4bδ) on Nakkholmen, Oslo—Asker. It has a characteristic subtriangular outline. The specimen is partly exfoliated, but preserved parts of the outer test show faint terrace lines near the margin.

Genus *Ogmasaphus* JAANUSSON, 1953

Type species: — *Asaphus praetextus* TÖRNQUIST, 1884, by original designation.

Remarks: — According to JAANUSSON (1953, p. 427) *Ogmasaphus* differs from *Asaphus* mainly in having as a rule more distinctly defined frontal area and a pygidium with as a rule more distinct pleural ribs, with a wider doublure, and with a distinct indication of a "Limbus" (a flattened border). As pointed out by JAANUSSON (1953, p. 427), species like *Asaphus* (*Neoasaphus*) *lepidus* and *A.* (*N.*) *glabratus* may also have a rather distinctly defined frontal area.

Although less pronounced than in the type species of *Ogmasaphus*, pleural ribs are likewise known in several species of *Asaphus*. As to the "Limbus", one may see very faint indications of it even in pygidia of *Asaphus* (*Neoasaphus*) *ludibundus*, type species of the subgenus

Neoasaphus. The two species originally assigned to *Ogmasaphus* differ from *Asaphus* in having better developed terrace lines on the outer surface of the pygidium. However, at least some such terrace lines occur even in several species of *Asaphus*. From the above it appears that several of the differences between *Asaphus* and *Ogmasaphus* only are differences in degree of relief, *Ogmasaphus* having a more strongly developed relief than *Asaphus*. Forms with high relief and forms with low relief (smooth forms) seem to occur in all kinds of shellbearing animals and need not necessarily indicate generic distinction; on the contrary, forms with high relief may often be very closely related to forms with low relief. JAANUSSON also mentioned the width of the pygidial doublure as a distinguishing character between *Ogmasaphus* and *Asaphus*. The difference is not great, and *Ogmasaphus stoermeri* n. sp. has a relatively narrow doublure, as compared with that of *Asaphus*. Thus not even the width of the pygidial doublure seems to be a reliable distinguishing character between the two genera. JAANUSSON (1953, p. 427) suggests that the genus *Ogmasaphus* may have developed from the group of *Ptychopyge cincta*. As pointed out by him, the pygidia of this group are very similar to those of *Ogmasaphus*. However, the cranidia of *Ogmasaphus* differ from those of *Ptychopyge* in having a much shorter frontal area. This may not be of great importance, but it is more suspiciuous that no cranidia of *Ogmasaphus* show even an indication of the little node behind the eyes so typical of *Ptychopyge*. On the whole I am inclined to believe that *Ogmasaphus* is closer related to *Asaphus* than to *Ptychopyge* and believe that the species assigned to *Ogmasaphus* may be regarded as, so to say, forms of *Asaphus* (*Neoasaphus*) with relatively strong relief. As a consequence, *Ogmasaphus* might perhaps rather be regarded as a subgenus of *Asaphus* (or of a genus *Neoasaphus*) than a distinct genus. However, since the relationship are not clear, I refrain here from any "Bessermachen" and retain *Ogmasaphus* as a separate genus. If the species described below are correctly assigned to *Ogmasaphus*, its species vary rather much in proportions, and it is possible that the genus *Ogmasaphus* contains several off-shoots from *Asaphus* (*Neoasaphus*). It is also possible that the genus *Ogmasaphus* should be distinguished from *Asaphus* (*Neoasaphus*) on other characters. Thus at least the group of *Asaphus* (*Neoasaphus*) *ludibundus* seems to differ from the species assigned to *Ogmasaphus* in having a steep front of the glabella.

Ogmasaphus jaanussoni n. sp.

Pl. 9, figs. 1—3.

1884 *Asaphus platyurus* (partim) — BRØGGER, p. 17 (Listed.)

Name: — The species is named in honour of Phil. Dr. Valdar Jaanusson (Palaeontological Institution, University of Uppsala).

Type data: — The holotype is an almost complete dorsal shield (P.M.O. no. 61519) from Ruseløkkveien in Oslo. Horizon unknown, probably lower Middle Ordovician. Collector unknown.

Material: — The description is based on three almost complete dorsal shields. They are all more less distorted, but show all the small genal spines. Additional material seems strangely enough to be rare. A detached pygidium and a fragmentary free cheek are tentatively assigned to this species. The specimens are preserved in limestone or marly shale.

Diagnosis: — A species of *Ogmasaphus* with the following characteristics: Small genal spines present. Cephalic doublure relatively narrow, only slightly more than half as wide as distance from eye to lateral cephalic margin. Cranidium with rather wide preocular cheek areas (about 1/3 as wide as glabella) and with bluntly rounded anterolateral corners. Outer part of pleurae about 1.5 times as wide (tr.) as inner part. Pygidium with relatively narrow doublure, reaching less than halfway from margin to dorsal furrow along 1st pleural furrow, and surrounding only about posterior sixth of axis. Dorsal surface of pygidium with numerous terrace lines, some of which crossing the axis.

Description: — The general features are seen in the illustrations. The following description is based on the holotype.

Cephalon with small genal spines. Outer margin evenly convex except for small pointed protrusion in front. Narrow depressed frontal area. Postocular cheeks about as wide (tr.) as occipital ring. Eyes about twice as long (long.) as distance from posterior margin. Preocular cheeks about 1/3 as wide as glabella. Bluntly rounded anterolateral corners. Sutural margin slightly concave behind anterolateral corners. Doublure only slightly wider than distance from eye to outer margin, chanelled along margin (as seen from above) and with terrace lines subparallel to margin. Slit-like panderian opening. Hypostome unknown.

Thorax with axis about 2/3 as wide as pleural region (the holotype is somewhat compressed). Fulcrum at about 2/3 of distance from dorsal furrow to lateral margin. Doublure with terrace lines and isolated Panderian openings. Inner margin of doublure poorly seen, apparently almost straight or slightly concave.

Pygidium about twice as wide as long (restored). Axis in front about half as wide as pleural region, and about 4/5 as long as pygidium. Outer surface with more or less transverse terrace lines. Doublure less than half as wide as pleural region along 1st pleural furrow and with terrace lines subparallel to margins. Inner margin of doublure subparallel to outer margin, except where it curves around posterior sixth of axis.

A single detached pygidium (P.M.O. no. 56580) agrees with that of the holotype, also in having a relatively narrow doublure, and may be conspecific. It is somewhat better preserved than the pygidia of the dorsal shields, and shows some characters which are poorly or not seen in those. The pleural ribs are double, being divided by the interpleural furrow into a thin anterior ridge and a broader posterior ridge. The outer surface of the pygidium shows a bend which corresponds in location to the inner margin of the doublure. The area outside this bend is somewhat depressed and more densely covered with terrace lines. Some terrace lines cross the axis.

Dimensions (in cm): —

Specimen	Dorsal	shield	Ceph.	Thorax	Pygidium	
	L.	W.	L.	L.	L.	W.
61519 (holotype) .	11.7	c.7.5	3.7	3.8	4.2	c.6.9
20289 (dors. sh.) .	—	c.6	—	2.9	c.3.2	5
61143 (dors. sh.) .	7.7	5.9	2.3	2.5	2.9	5.5
56580 (pyg.)	—	—	—	—	2.6	c.5

The holotype, 11.7 cm long, represents the largest specimen present.

Occurrence: — *Ogmasaphus jaanussoni* n. sp. occurs in the lower Middle Ordovician, excact horizon not known, probably Ampyx limestone (4aβ) or slightly above or below.

Oslo—Asker: Ruseløkkveien in Oslo (horizon?); Oslo (4a?); Oslo? (horizon?); ? Huk on Bygdøy (4a?); ? Building ground of Rådhuset (City Hall) in Oslo (4a?); ? Bjerkås in Asker (4aα).

Ogmasaphus kiaeri n. sp.

Pl. 10, figs. 1—12.

1887 *Ptychopyge glabrata* Ang. — Brøgger, p. 17. (Recorded.)
1887 *Asaphus platyurus* (pars) — Brøgger, p. 17. (Recorded.)
1887 *Ptychopyge* cf. *glabrata* Ang. (pars) — Brøgger, p. 19. (Recorded.)
1940 *Asaphus platyurus* Ang. — Grorud, pp. 159—160. (Recorded.)
1953 Einer *Ogmasaphus*-Art — Jaanusson, p. 427. (Mentioned.)

Name: — The species is named in honour of the late Director of Paleontologisk Museum in Oslo, Professor, Dr. Johan Kiær, who collected the holotype as well as other specimens of it.

Type data: — The holotype is an almost complete, enrolled dorsal shield (P.M.O. no. 19112) from the Ampyx limestone (4aβ) at S. Kojatangen, Asker. Collected by J. Kiær in 1898.

Material: — Numerous detached parts of the shield and a few more or less complete dorsal shields. Preserved in limestone.

Diagnosis: — A species of *Ogmasaphus* with the following characteristics: No genal spine. Cephalic doublure about twice as wide as distance from eye to outer cephalic margin. Cranidium with preocular cheek areas somewhat less than 1/3 as wide as glabella and with well rounded anterolatedral corners. Sutural margin practically straight behind anterolateral corners. Pygidium with doublure reaching about half way from margin to dorsal furrow along anterior pleural furrow, and surrounding about posterior fifth of axis. Dorsal surface of pygidium with numerous, chiefly short terrace lines.

Description: — The general features are seen in the illustrations. The description is based on the holotype. Additional information from other specimens is added in parenthesis.

Cephalon with narrow depressed frontal area. Genal corners broken (other specimens show angular corners without spine and a slightly convex, almost straight posterior border of the free cheek). Postocular cheek areas about as wide as occipital ring. Eyes about twice as long (long.) as distance from posterior margin. Preocular cheek areas less than 1/3 as wide as glabella. Anterolateral corners well rounded. Sutural margin practically straight behind anterolateral corners. Cephalic doublure about twice as wide as distance from eye to outer margin, chanelled along margin (as seen from above) and with terrace lines subparallel to margin. Slit-like panderian opening. Hypostome unknown.

Thorax with fulcrum closer to dorsal furrow than to lateral margin. Doublure with terrace lines. (Other specimens show the isolated panderian openings and the slightly convex, almost straight inner margin of the pleural doublure).

Pygidium of holotype exfoliated and somewhat distorted. It shows, however, that the doublure is about half as wide as pleural region along anterior pleural furrow, and the presence of faint terrace lines on the inner impression of the test, indicating well developed terrace lines on the outer surface. (Other, probably conspecific pygidia shows that the ribs are double as in *O. jaanussoni* n. sp., that the outer surface of the test has numerous mainly short terrace lines, and that the doublure is faintly concave.)

(A poorly preserved but possibly conspecific hypostome is of the *Ogmasaphus* type.)

Dimensions (in cm): —

Specimen	Dorsal shield		Cephal.	Thorax	Pygidium	
	L.	W.	L.	L.	L.	W.
19112 (holotype) .	—	c.5.5	3.0	—	3.6	—
3490 (dors. sh.) .	c.4.2	c.2.5	1.4	1.5	c.1.3	—
4098 (pyg.)	—	—	—	—	1.9	3.4

The largest parts of the shield in the present material suggests a total length of the dorsal shield of about 10 cm.

Remarks: — *Ogmasaphus kiaeri* n. sp. resembles *O. jaanussoni* n. sp. but differs in that it lacks genal spines and has a wider doublure, both in the cephalon and in the pygidium. Furthermore, the anterolateral corners of the cranidium are more pointed in *O. kiaeri* n. sp. and the suture is straighter between the eyes and the anterolateral corners. *O. kiaeri* n. sp. apparently resembles *O. glabratus* (ANGELIN, 1854), which, however, is not yet well enough known to allow a detailed comparison and which seems to be slightly younger.

Occurrence: — *Ogmasaphus kiaeri* n. sp. occurs rather frequently in the Ampyx limestone (4aβ).

OSLO—AKER: Bygdøy in Oslo (4aβ); Fornebu in Bærum (hor. ?); Terneholmen in Asker (4aβ); Gyssestad (4aβ); Holmen at Vollen in Asker (4aβ); Elnestangen in Asker (4aβ); S. Kojatangen in Asker (4aβ).

Ogmasaphus multistriatus n. sp.

Pl. 6, figs. 13—17.

1887 Ny *Asaphus*-art (new species of *Asaphus*) — BRØGGER, p. 17. (Mentioned.)
?1909 *Pseudasaphus globifrons* var. — HOLTEDAHL, pp. 7, 28. (Mentioned.)
1909 *Asaphus* n. sp. aff. *A. striatus* S. & B. — HOLTEDAHL, pp. 7, 28. (Mentioned.)

Name: — The name *multistriatus* alludes to the large number of terrace lines on the pygidial doublure.

Type data: — The holotype is a pygidium (P.M.O. no. 36822a) from the Ogygiocaris shale (4aα) at Storhamar in Hamar—Nes.

Remarks: — *Ogmasaphus multistriatus* n. sp. is based on the pygidium. It is usually not recommendable to erect a species on the pygidium alone, but it has been done here because the pygidium is rather characteristic and frequently met with. No complete specimens have been found, but some cranidia and cephala which are associated with the characteristic pygidia may belong to the same species. The holotype has been chosen partly because it occurs on the same small chip of rock as a small cranidium. The associated cephala are rather similar to that of *O. kiaeri* n. sp. If they really belong to *O. multistriatus* n. sp., it is possible that *multistriatus* should rather be regarded as a subspecies of *O. kiaeri* n. sp. However, *O. multistriatus* apparently appears at a lower horizon than *O. kiaeri* n. sp.

Diagnosis: — A species of *Ogmasaphus* with very densely striated pygidial doublure. Pygidial doublure reaching more than halfway from margin to dorsal furrow at anterior pleural furrow.

Description: — Pygidium about twice as wide as long. In well-preserved specimens the pleural ribs are seen to be double as in *O. jaanussoni* n. sp. Outer surface of test with terrace lines. Doublure more than half as wide as pleural areas at anterior pleural furrow and surrounding posterior fifth of axis. Doublure markedly concave along outer margin, and with densely spaced terrace lines (5—6 in 1 mm in a pygidium about 2 cm long).

A single, poorly preserved specimen consists of the pygidium, thorax, and a free cheek. Only a tiny fragment is preserved of the thoracic doublure, but it shows that this, too, is ornamented with densely spaced terrace lines. Neither this nor other associated free cheeks show whether genal spines are present or not. A few associated and probably conspecific cranidia are all rather small, but seem to resemble the cranidium of *O. kiaeri* n. sp.

Dimensions of pygidia (in cm): —

Specimen	L.	W.	Number of terrace lines in 1 mm on the doublure.
21921	3.4	c.6.2	c.2
21922	1.35	c.2.6	c.6
58928	1.9	c.3.6	c.6
6007	2.2	c.4.2	c.5

A single pygidium suggests a total length of the dorsal shield of almost 10 cm. The other pygidia present suggest a total length of about 6 cm or less.

Occurrence: — Pygidia of *O. multistriatus* occur in the Ogygiocaris shale (4aα_3-$_4$) and the Ampyx limestone (4aβ).

OSLO—ASKER: Terneskjær in Asker (4aβ); Håkavik in Asker (4aα); Vollen in Asker (4aβ), Gyssestad (4aβ); Fornebu in Bærum (4a?); Steilene (4aβ). — HADELAND; Melbostad (4aα); Hovstangen, Gran (4aα). HAMAR—NES: Helgøya (4aα); Storhamar (4aα).

Ogmasaphus stoermeri n. sp.

Pl. 11, figs. 1—6.

1884 *Asaphus* confr. *platyurus* — BRØGGER, p. 259. (Recorded.)

Name: — The species is named in honour of Professor, Dr. Leif Størmer, who collected several of the specimens preserved in the Palaeontological Museum.

Type data: — Holotype is a small but fairly complete and well preserved dorsal shield (P.M.O. no. 4684) from the Ogygiocaris series (4aα) at Teigen slate pit, Eiker. Collected by M. Langeberg and presented to the Palaeontological Museum by S. Swensen in 1892.

Material: — A few more or less complete dorsal shields and numerous detached plates. The specimens occur in a slightly metamorphosed mudstone and are more or less compressed.

Diagnosis: — A species of *Ogmasaphus* with the following characteristics. Angular genal corners but no genal spines. Cephalic doublure almost 2/3 as wide as distance from eye to outer margin. Cranidium with preocular cheek areas about 1/6 as wide as glabella and with well rounded anterolateral corners. Thorax with pleural regions wider than axis and fulcrum closer to dorsal furrow than to lateral margin. Pygidium with narrow axis less than half as wide as pleural region in front. Pygidial doublure markedly less than half as wide as pleural region in front, with inner margin subparallel to outer margin of pygidium except where it curves around posterior tip of axis.

Description: — The general features are seen in the illustrations.

Cephalon evenly rounded in front and with only a narrow (long.) and poorly defined frontal area. Genal corners angular and without spines. Preocular cheek areas rather narrow, about 1/6 as wide as glabella at the rounded anterolateral corners. Eyes nearer to posterior than to anterior cephalic margin and about twice as long (long.) as their distance from posterior margin. Postocular cheek areas slightly narrower (tr.) than occipital ring. Cephalic doublure almost 2/3 as wide as distance from eye to outer margin and with relatively openly spaced terrace lines subparallel to margins of doublure. Nature of panderian opening unknown. Hypostome of *Asaphus* type.

Thorax with pleural regions wider (tr.) than axis. Fulcrum closer to dorsal furrow than to lateral margin. Doublure with terrace lines. Nature of panderian openings and inner margin of doublure unknown.

Pygidium about twice as wide as long. Axis narrow (in front less than half as wide as pleural region), short (reaching about 3/4 of distance to posterior margin), and tapering relatively sharply rearwards with rather straight (not concave) dorsal furrows. Axis with about 11 rings and an endlobe; the posterior rings are poorly defined. Paradoublural line developed as a distinct bend or even as a thin ridge, but this character may have been exaggerated by the flattening of the specimens. Pleural ribs and furrows faintly developed inside the paradoublural line. Terrace lines well developed both outside and inside paradoublural line; one terrace line is connected across axis in each ring. Pygidial doublure markedly less than half as wide as pleural region in front, and with inner margin subparallel to outer margin except where it curves around posterior tip of axis. Doublure with rather openly spaced terrace lines.

Dimensions (in cm): —

	Dorsal shield		Cephal.	Thorax	Pygidium	
	L.	W.	L.	L.	L.	W.
4684 (holotype) .	4.3	3.2	1.3	1.5	1.5	c.3.2
4682 (dor. sh.) . .	5.9	c.4.4	1.8	2.0	2.1	c.4.3
60509 (dor. sh.) . .	4.65	c.3.4	1.4	1.75	1.5	3.3
60365 (pygidium)	—	—	—	—	3.6	c.7.0
60379 (pygidium)	—	—	—	—	4.05	c.8.0
72069 (pygidium)	—	—	—	—	4.8	9.4

The largest pygidium present (P.M.O. no. 72069) indicates an overall length of the dorsal shield of about 14 cm.

Remarks: — The pygidium seems to be especially characteristic of this species and distinguishes it from all other species assigned to *Ogmasaphus*.

Occurrence: — *Ogmasaphus stoermeri* n. sp. occurs in $4a\alpha_1$, apparently also in $4a\alpha_2$, and possibly in $4a\alpha_3$.

Eiker—Sandsvær: Teigen shale quarry ($4a\alpha$); Muggerudkleiva ($4a\alpha_1$); Vestfossen ($4a\alpha$); Krekling ($4a\alpha$). — Skien—Langesund: Rognstrand ($4a\alpha$); Bø in Gjerpen ($4a\alpha$).

Ogmasaphus sp.

Pl. 12, fig. 9.

1909 *Asaphus latus*, Pand. var. — Holtedahl, pp. 9, 29, 40. (Recorded from the Cephalopod shale.)

Remarks: — A few pygidia (some with attached thoracic segments) from the Cephalopod shale in the Mjøsa districts do not seem to agree with any of the above described species. More material is needed to give a full description of the present form. The pygidium has a relatively narrow axis and the pygidial doublure is less than half as wide as the pleural regions in front. Terrace lines are developed in a marginal zone about as wide as the doublure.

Occurrence: — *Ogmasaphus* sp. occurs in nodules in the Cephalopod shale.

Toten: Arnestad; Hammerstad. — Hamar—Nes: Hovindsholm on Helgøya.

Genus *Pseudoasaphus* SCHMIDT, 1901

Synonym: — *Pseudasaphus* SCHMIDT, 1904 (*nom. null.*).
Type species: — *Ptychopyge globifrons* EICHWALD, 1875, by subsequent designation by REED, 1930.

Pseudoasaphus limatus JAANUSSON, 1953

Pl. 9, fig. 4; pl. 13, figs. 1—5.

1884 *Asaphus* cfr. *undulatus* STEINH. — TÖRNQUIST, p. 69, pl. II, fig. 22. (Descr. and fig. of pygidium.)
1884 *Asaphus nobilis* BARANDE aff. — BRØGGER, pp. 261, 262. (Recorded.)
1953 *Pseudasaphus?* sp. — STØRMER, pp. 74, 75, 80. (Recorded.)
1953 *Pseudasaphus limatus* n. sp. — JAANUSSON, p. 421, pl. III, figs. 6—7. (Descr. and figs. of pygidia.)

Type data: — Holotype (by original designation) is a pygidium (P.M.O. no. 58931, figured by JAANUSSON, 1953, pl. III, fig. 7) from 4aβ or 4bα at Fornebu Air Field, Bærum in Oslo-Asker.

Description: — The pygidium is adequately described by JAANUSSON (1953, p. 421). It may added be that a large fragmentary pygidium (P.M.O. no. 72069) shows fine pits on the upper surface of the test. (Pl. 9, fig. 4). A few more or less fragmentary thoracic shields are known, some with pygidium attached. The axial rings are ornamented with curved terrace lines subparallel to the anterior margin of the articulating half ring. The pleural tips are not well preserved, but seem to be pointed at their posterolateral corners. The pleurae are ornamented with terrace lines directed outwards and forwards. The nature of the inner margin of the thoracic doublure is unknown. Fine pits may be seen on the outer surface of the thorax, especially on the axis.

Some fragments of cephala are probably conspecific. An incomplete cephalon (P.M.O. no. 58911) is attached to a part of the thorax. Its cranidium resembles an isolated, but larger cranidium (P.M.O. no. 40355). The cranidia recall those of *P. tecticaudatus* (STEINHARDT, 1874), but their preocular cheek areas are wider, since the facial sutures diverge more strongly in *P. limatus*. In the one specimen where the anterior margin is fully preserved, this is less pointed than in *P. tecticaudatus*. The material of free cheeks is very fragmentary, but includes part of a stout genal spine. The cephalic doublure is unknown. A couple of fragmentary and poorly preserved large hypostomes are of the *Pseudoasaphus* type.

Variations in the pygidium: — As discussed by JAANUSSON (1953, p. 422) the main differences between the pygidia of *P. limatus* and *P. tecticaudatus* are those between the terrace lines on the axis and on the pleural regions close to the axis. In *P. tecticaudatus* the posterolaterally oriented terrace lines are strongly developed on the pleural regions close to the axis and there is a strong transversal terrace line across the whole of each axial ring. In *P. limatus* the terrace lines on the axis are more numerous and only rarely traverse the whole of the axial ring, and in the pleural regions the anterolateral direction of the terrace lines predominate also in the area close to the axis. However, in some pygidia here included in *P. limatus* the terrace lines in the axis or in the pleural regions close to the axis agree better with those of *P. tecticaudatus*. In a single specimen, unfortunately not too well preserved, the terrace lines both on the axis and on the pleural regions seem to agree best with those of *P. tecticaudatus*, and it is possible that this specimen belongs to *P. tecticaudatus*. In any case the pattern and also the density of the terrace lines vary somewhat in *P. limatus*. Furthermore, small pygidia of *P. limatus* have a concave posterior margin, whereas large pygidia are almost straight (truncated) posteriorly.

Dimensions: — The smallest pygidium present (RM. no. Ar 37755) is 2.7 cm long and about 4.6 cm wide (restored). The holotype pygidium is 3.9 cm long and 5.2 cm wide (restored). A large pygidium (P.M.O. no. 58938) is 7.5 cm long and about 9.5 cm wide (restored). The largest pygidium present (P.M.O. no. 57447) is 8.9 cm long and about 13.6 cm wide (restored), suggesting a total length of the dorsal shield of about 25 cm.

Occurrence: — *Pseudoasaphus limatus* occurs in the Ampyx limestone (4aβ) and possibly also in the Ogygiocaris series (4aα) and the Lower Chasmops shale (4bα). It also occurs in the Echinosphaerites beds and apparently in the Bryozoan beds in Skien—Langesund.

OSLO—ASKER: Oslo centre (4), Bygdøy Allé near Frogner Church (4), Hjortnestangen (4a?), and on Bygdøy in Oslo; Fornebu Air Field (4aβ or 4bα?) in Bærum; Gyssestad (4aβ); Djuptrekkodden (4aβ?), Håkavik (4aβ), and Vollen (4aβ) in Asker. — EIKER—SANDSVÆR:

Recorded from 4aα. — RINGERIKE: Norderhov Church (4aβ). — HADELAND: Kløvstad in Gran (4aβ?), — SKIEN—LANGESUND: Gravestranda at Frierfjord. — SWEDEN.

Pseudoasaphus sp.

Pl. 13, fig. 6.

Remarks: — A single, 5.7 cm long pygidium from the Coelosphaeridium beds between Tørud and Brattberg (Ringsaker) apparently belongs to *Pseudoasaphus*. The surface ornamentation is not preserved, an it is hardly possible to determine the species until more material has been collected.

Genus *Pseudobasilicus* REED, 1930

Type species: — *Ptychopyge lawrowi* SCHMIDT, 1898.

Pseudobasilicus cf. *kuckersianus* (SCHMIDT, 1898)

Pl. 13, fig. 7.

Remarks: — A single pygidium, 1.9 cm long, from the Ampyx limestone (4aβ) near Gyssestad, Oslo-Asker, resembles the small pygidium of *Pseudobasilicus kuckersianus* figured by SCHMIDT (1904, pl. IV, fig. 14).

Pseudobasilicus cf. *kegelensis* (SCHMIDT, 1898)

Pl. 14, figs. 1, 4, 8.

1909 *Basilicus Kegelensis*, F. SCHM. — HOLTEDAHL, pp. 20, 27, 32. (Recorded.)

Material: — Two cranidia, a pygidium and a few fragments of dorsal shields.

Remarks: — The two cranidia agree fairly well with that of *Pseudobasilicus kegelensis* figured by SCHMIDT (1904, pl. V, fig. 1), as far as they can be compared. The associated pygidium is more triangular and with a narrower border than the pygidium figured by SCHMIDT (1904, pl. V, fig. 3), but this may possibly be due to its smaller size. However, for the time being it seems safest to refer to the Norwegian material as *P.* cf. *kegelensis*.

Dimensions: — The larger of the two cranidia suggests a total length of the dorsal shield of about 7 cm, but other fragments indicate that this form may have reached a greater size.

Occurrence: — *Pseudobasilicus* cf. *kegelensis* occurs in the Cyclocrinus beds.

HAMAR—NES: Furuberget.

Pseudobasilicus? sp.

Pl. 14. figs. 2—3.

Remarks: — Two incomplete cranidia from the Cyclocrinus beds of Furuberget (Hamar—Nes) are rather smooth and resemble somewhat *Isotelus*. However, they have a distinct glabellar node, faint indications of basal glabellar furrows, and the eyes are situated further forwards than in *Isotelus*. They probably belong to a smooth species of *Pseudobasilicus* or possibly of *Pseudoasaphus*.

Genus *Pseudomegalaspis* JAANUSSON, 1953

Type species: — *Megalaspis formosa* TÖRNQUIST, 1884, by original designation.

Remarks: — To the diagnosis of the genus given by JAANUSSON (1953, p. 451) may be added that genal spines are present.

Pseudomegalaspis patagiata (TÖRNQUIST, 1884)

Pl. 12, figs. 1—7.

1884 *Megalaspis patagiata* n. sp. — TÖRNQUIST, p. 82, pl. III, figs. 15—17. (Descr. Figs. of incomplete cranidium and 2 pygidia.)

1887 *Megalaspis* n. sp. — BRØGGER, p. 16. (Recorded.)

1909 *Megalaspis patagiata* — HOLTEDAHL, pp. 7, 28. (Recorded.)

1953 *Pseudomegalaspis patagiata* — STØRMER, pp. 58, 83, 90, 97, 103, 109. (Recorded.)

1953 "*Megalaspis*" s.p — STØRMER, p. 109. (Recorded.)

1953 *Pseudomegalaspis patagiata* (TÖRNQUIST, 1884) — JAANUSSON, p. 456, pl. IX, figs. 4—7; pl. X, fig. 1; text fig. 5(9). (Descr. Figs. of dorsal shield and parts of dorsal shields.)

1953 *Pseudomegalaspis formosa* (TÖRNQUIST, 1884) (partim) — JAANUSSON, p. 452. (Norwegian material only, pl. X, figs. 2 and 3.)

Type data: — The holotype (by monotypy) is an enrolled dorsal shield (S.G.U. no. c. 66) from the Schroeteri beds of Kårgärde, Siljan area, Dalarna, Sweden.

Norwegian material: — A few more or less complete dorsal shields and numerous detached parts of the shield. Preserved in limestone, more or less distorted.

Remarks: — An almost complete dorsal shield (P.M.O. no. 56556, pl. 12, figs. 1—2), which was assigned to *Pseudomegalaspis formosa* TÖRNQUIST, 1884)) by JAANUSSON (1953, p. 455, pl. X, figs. 2—3), is associated with a smaller pygidium with about the same proportions. Both specimens appear to be deformed by lateral compression and/or elongation. In the same rock sample there are two other pygidia which are relatively somewhat shorter and thus agree with *P. patagiata*. The two latter pygidia are oriented normal to the axis of elongation in the other specimens and it seems probable to me that all 4 specimens only represent two different types (L-forms and W-forms) of deformation of the same species.

According to JAANUSSON (1953, p. 459), the main differences between *P. formosa* and *P. patagiata* are that 1) the cephalic and pygidial margin are more or less semicircular in *P. patagiata* and subparabolic in *P. formosa*, 2) the anterior border of the glabella is rather weakly convex in *P. patagiata* and evenly rounded in *P. formosa*, 3) the pygidial facets are relatively somewhat shorter in *P. patagiata*, and 4) the anterolateral corners of the facets more rounded in *P. patagiata* than in *P. formosa*. As to points 1) and 2), these differences could be readily explained if *P. patagiata* represents the W-form and *P. formosa* the L- or O-form. This is probably not true of points 3) and 4), but these differences are very small and hardly of great importance.

The holotype pygidium of *P. formosa* is ornamented with terrace lines all over the area outside the paradoublural line as well as on the rib furrows, whereas the lectotype pygidium of *P. patagiata* chiefly has the terrace lines concentrated in a zone along the paradoublural line. However, as pointed out by JAANUSSON (1953, p. 458) some pygidia of *P. patagiata* are covered with terrace lines all over the outer surface. In Norwegian pygidia, which in any case would have been assigned to *P. patagiata*, the development of the terrace lines varies from forms with terrace lines only along the paradoublural line to forms where they cover practically the whole of the test. The pattern of the terrace lines can thus hardly be used to distinguish between *P. formosa* and *P. patagiata*.

The holotype pygidium of *P. formosa* is relatively somewhat longer than the lectotype pygidium of *P. patagiata*. However, intermediate forms occur as well in the Norwegian material, and it is important that all the relatively shortest pygidia appear to be longitudinally compressed and/or transversely widened (W-forms). The dorsal shield (P.M.O. no. 3695) figured by JAANUSSON (1953, pl. X, fig. 1) is rather an extreme W-form. Actually the differences in proportions are greater between the pygidium of this specimen and of the lectotype of *P. patagiata* than between those of the latter and the holotype pygidium of *P. formosa*.

It seems rather probable to me that the Norwegian specimen previously referred to *P. formosa* is conspecific with those assigned to *P. patagiata*. This, of course, does not imply that the types of *P. formosa* and *P. patagiata* necessarily are conspecific. If they are, *P. formosa* would represent the L-form or O-form and *P. patagiata* the W-form of the same species. This could perhaps be proved or disproved by examining a great number of specimens from their common type locality in Sweden and especially search for their eventual type of deformation.

Description: — A few additions may be made to the description given by JAANUSSON (1953). Some specimens with the genal corners preserved show that well-developed genal spines are present. This is true also of the specimen (P.M.O. no. 56556) previously assigned to *P. formosa*. The cephalic doublure is slightly wider than half the distance from the eye to the cephalic margin. Some well-preserved free cheeks and pygidia show that the outer surface of the test is ornamented with very small pits. A few associated hypostomes which may be conspecific, are of the *Asaphus* type.

Dimensions: — See JAANUSSON (1953, p. 458). The largest part present (a pygidium) suggests a total length of the dorsal shield of about 10 cm.

Occurrence: — *Pseudomegalaspis patagiata* occurs in Norway in the upper part of the Ogygiocaris series, in at least the uppermost part of the Upper Didymograptus shale (4aα_2), in the Ogygiocaris shale s.s. (4aα_3), and probably also in the *Trinucleus bronni* beds (4aα_4).

Oslo—Asker: Huk on Bygdøy (4aα_3); Vekkopp on Bygdøy (4aα_3); Building site of the Vigeland Fountain in the Frogner Park in Oslo (4aα_3); Håkavik, Engervik, and Elnestangen in Asker (4aα_3), and several other localities. — Eiker—Sandsvær: Vestfossen (4aα); Muggerudkleiva (4aα). — Ringerike: (4aα). — Hadeland: Lunner in Gran (4aα_3). — Toten: (4aα_3). — Hamar—Nes: Helgøya (4aα); Nes (4aα); Flakstadelva (4aα). — Ringsaker: Furnes Church (4aα). — Sweden.

Pseudomegalaspis? sp.

Pl. 12, fig. 8.

Remarks: — A single, somewhat worn dorsal shield resembles *Pseudomegalaspis patagiata*, but differs *i.a.* in having wider preocular cheek (about 1/3 as wide as glabella), in apparently lacking anterior pits, in having a relatively longer pygidial axis and in having a less concave border of the pygidial doublure (as seen from above). No genal spines are preserved, but the preservation of the genal corners is rather poor. It is hard to tell how wide the pygidial doublure is, but it appears to be rather narrow, and in this character the specimen resembles *Pseudomegalaspis*. The cephalon, however, also resembles that of *Ogmasaphus*. The outer surface of the test is too poorly preserved to show whether terrace lines were present or not.

Dimensions: — The specimen (P.M.O. no. 36832) is 7.3 cm long.

Occurrence: — In a loose limestone lens, probably from the Cephalopod shale, Hamar—Nes.

Subfamily Isotelinae Angelin, 1854

Genus *Isotelus* DeKay, 1824

Type species: — *Isotelus gigas* DeKay, 1824.

Isotelus cf. *platyrhachis* Steinhardt, 1874

Pl. 14, figs. 5—7.

1897 *Asaphus* cf. *Powisii*, Murch. — Kiær, pp. 39, 73. (Recorded.)
1909 *Asaphus* aff. *Powisii*, Murch. — Holtedahl, pp. 20, 23, 32. (Recorded.)

Material: — Several more or less fragmentary detached parts of the dorsal shield, preserved in limestone.

Remarks: — The cranidia resemble that assigned to *Isotelus* *platyrhachis* by SCHMIDT (1901, pl. X, fig. 14) but expands somewhat less in front of the eyes. As in other species of *Isotelus*, no glabellar node is developed. The free cheeks have a well developed genal spine and a flattened, slightly concave border, which widens posteriorly. The doublure is strongly concave, as seen from above. Two fragmentary hypostomes show that the hypostome is of the *Isotelus* type with short anteromedian body and with stout posterior projections with a subtriangular cross section (with ventral "keel"), as in the hypostome of *I. remigum* illustrated by SCHMIDT (1901, pl. X, figs. 17, 17a). Only fragments of pleurae are present of the thorax. Pygidium elongated subtriangular and agreeing rather well with the pygidium of *I. platyrhachis* figured by SCHMIDT (1901, pl. X, fig. 16). The border is depressed. Two rather small pygidia (6 and 9 mm long) differ in being relatively shorter and wider, but may belong to the same species since the length of the pygidium increases with growth in relation to widt also in *e.g. I. gigas*. The fragmentary character of the material impedes a comparison with other forms, but the present form is probably rather close to the species assigned to *I. platyrhachis* by SCHMIDT (1901).

Dimensions: — The most complete detached parts of the shield all belong to rather small individuals. Fragments of larger individuals indicate that the form may have reached a total length of 15 cm or more.

Occurrence: — *Isotelus* cf. *platyrhachis* occurs in the Mjøsa limestone and in the underlying Cyclocrinus beds in Hamar—Nes. Most of the material comes from the uppermost part of the Mjøsa limestone, where some beds are rather rich in fragments of it. I have not been able to locate the specimens assigned to *Isotelus* cf. *gigas* by BRØGGER (1884, p. 265) from the Encrinite limestone in Skien—Langesund. It is possible that they belong to the same form as in the contemporaneous Mjøsa limestone.

HAMAR—NES: Bergvika on Helgøya; Furuberget. — ?SKIEN—LANGESUND.

Present determination of Middle Ordovician asaphids previously recorded from the Oslo region.

Some species which were recorded previously, have been redeterminated, and the generic name has been changed in some species. The following list may be useful when consulting earlier papers.

Name used by	Name used in the present paper
Brøgger, 1884	
Asaphus cf. platyurus	*Ogmasaphus stoermeri* n. sp.
Asaphus acuminatus	*Asaphus* (*Neoasaphus*) *ludibundus*
Asaphus nobilis aff.	*Pseudoasaphus limatus*
Isotelus cf. *gigas*	*? Isotelus* cf. *platyrhachis*
Brøgger, 1887	
Asaphus acuminatus	*Asaphus* (*Neoasaphus*) *ludibundus*
Ny *Asaphus*-art. (New sp. of *A.*)	*Ogmasaphus multistriatus* n. sp.
Asaphus platyurus	*Ogmasaphus jaanussoni* n. sp. and *Ogmasaphus kiaeri* n. sp.
Asaphus cf. *acuminatus*	*Asaphus* (*Neoasaphus*) *ludibundus*
Ptychopyge glabrata	*Ogmasaphus kiaeri* n. sp.
Ptychopyge cf. *glabrata*	*Ogmasaphus kiaeri* n. sp. and *Asaphus* (*Neoasaphus*) *ludibundus*
Ptychopyge cf. *brachyrhachis*	? (specimens not located.)
Megalaspis n. sp.	*Pseudomegalaspis patagiata*
Holtedahl, 1909	
Asaphus n. sp. aff. *A. striatus* (pyg.)	*Ogmasaphus multistriatus* n. sp.
Pseudasaphus globifrons var. (ceph.)	*Ogmasaphus multistriatus* n. sp.
Asaphus n. sp.	*Asaphus* (*Neoasaphus*) *ludibundus*
Asaphus latus var.	*Ogmasaphus* sp.
Asaphus lepidus var.	? (specimens not located.)
Asaphus lævigatus	? (specimens not located.)
Megalaspis patagiata	*Pseudomegalaspis patagiata*
Basilicus kegelensis	*Pseudobasilicus* cf. *kegelensis*
Basilicus aff. *Powisii*	*Isotelus* cf. *platyrhachis*
Størmer, 1953	
Ogygiocaris dilatata	*Ogygiocaris dilatata*
Ogygiocaris dilatata sarsi	*Ogygiocaris sarsi* (3 subsp.)
Pseudomegalaspis patagiata	*Pseudomegalaspis patagiata*
Pseudasaphus sp.	*Pseudoasaphus limatus*
Pseudasaphus ? sp.	*Pseudoasaphus limatus*
Asaphus ludibundus	*Asaphus* (*Neoasaphus*) *ludibundus*
Asaphus sp.	*Ogmasaphus kiaeri* n. sp. and *Asaphus* (*Neoasaphus*) *ludibundus*
Asaphus (*Neoasaphus*) *bottnicus*	*Asaphus* n. sp. (transition beds.)

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Manuscript received May 13, 1960.
Printed November 1960.

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Ogygiocaris dilatata	X	X	?	?	?	—	—	—	—	—	—	—	—	—	X	X	X	X	X	—	—	—	—
« *striolata striolata*	—	X	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	X	—	—	—	—
« *striolata corrugata*	—	X	X	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—
« *sarsi sarsi*	?	?	X	?	—	—	—	—	—	—	—	—	—	—	X	X	X	—	—	—	—	X	—
« *sarsi regina*	—	—	?	?	—	—	—	—	—	—	—	—	—	X	X	—	—	X	—	X	X	X	—
« *sarsi delicata*	—	—	—	X	?	—	—	—	—	—	?	—	—	—	X	—	—	—	—	X	X	X	X
Asaphus (*Neoasaphus*) *heintzi*	—	—	—	—	—	X	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—
« « *ludibundus*	—	—	—	—	X	X	X	—	—	—	—	X	—	—	X	X	—	—	X	—	X	—	—
« « cf. *ludibundus* .	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	X	—
« (*Neoasaphus ?*) sp. A ...	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	X	—	—	—	—	—	—	—
« « sp. B	—	—	—	—	—	—	—	—	X	—	—	—	—	—	X	—	—	—	—	—	—	—	—
Ogmasaphus jaanussoni..........	—	—	—	?	?	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—
« *kiaeri*	—	—	—	—	X	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—
« *multistriatus*	—	—	X	X	X	—	—	—	—	—	—	—	—	—	X	—	—	—	—	X	—	X	—
« *stoermeri*	X	X	?	—	—	—	—	—	—	—	—	—	—	—	—	X	X	—	—	—	—	—	—
« sp.	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	X	X	—
Pseudoasaphus limatus	—	—	?	?	X	?	—	—	—	—	—	—	—	—	X	X	X	—	—	X	—	—	—
« sp.	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	X
Pseudobasilicus cf. *kuckersianus* ..	—	—	—	—	X	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—
« cf. *kegelensis*	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	X	—
« ? sp.	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	X	—
Pseudomegalaspis patagiata	—	X	X	X	—	—	—	—	—	—	—	—	—	—	X	—	X	—	X	X	X	X	X
« ? sp.	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	X	X	—
Isotelus cf. *platyrhachis*	—	—	—	—	—	—	—	—	—	?	—	—	X	X	—	?	—	—	—	—	—	X	—

PLATES 1—14

The photographs, which were taken by Miss B. Mauritz in co-operation with the author, are not retouched.

The specimens were given a light coating of ammonium chloride before photographing.

P.M.O. = Palaeontological Museum, Oslo.
P.I.L. = Palaeontological Institute, Lund.
P.I.U. = Palaeontological Institute, Uppsala.
RM. = Swedish Museum of Natural History, Palaeozoological department.

PLATE 1

All × 0.8

Ogygiocaris dilatata (BRÜNNICH, 1871).

Fig. 1. Dorsal shield, *lectotype*. Evidently 4a*α*. From near Fossum Iron works, north of Skien, Skien—Langesund. BRÜNNICH's specimen. Mineralogisk Museum, Copenhagen. × 0.8.

Fig. 2. Dorsal shield without free cheeks. 4a*α*. Eiker. Lectotype of *O. dilatata* var. *stroemi* ANGELIN, 1872. P.M.O. no. 67032. × 0.8.

Fig. 3. Cranidium retaining convexity. 4a*α*. Muggerudkleiva, Eiker—Sandsvær. Coll. L. Størmer, 1925—27. P.M.O. no. 60441. × 0.8.

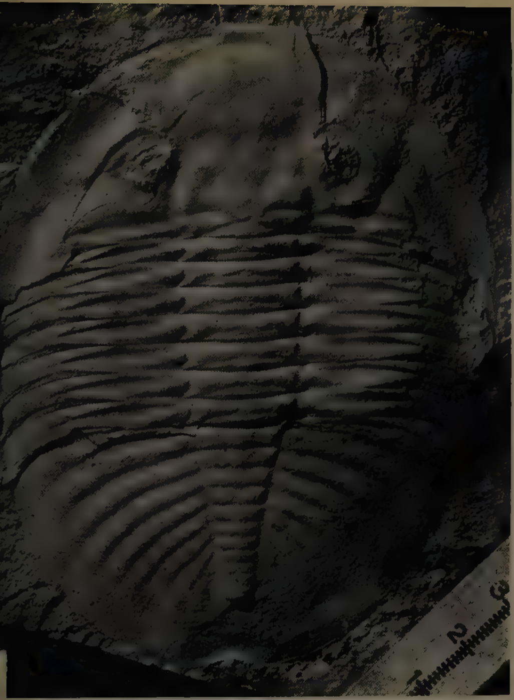
Fig. 4. Cranidium and parts of free cheeks. The anterior lobe shows traces of the parafrontal band and a similar band inside it. 4a*α*. Muggerudkleiva, Eiker—Sandsvær. Coll. L. Størmer, 1925—27. P.M.O. no. 60451. × 0.8.

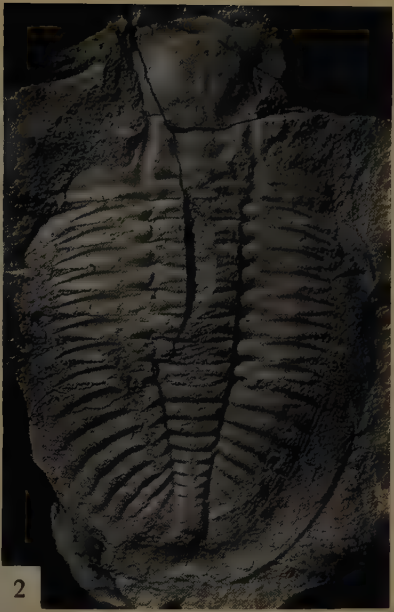
Fig. 5. Cranidium, strongly compressed, showing median ridge and traces of parafrontal band and a similar band inside it. 4a*α*. N. Fossum, Bø, Gjerpen, Skien—Langesund. Coll. G. Holm, 1879. RM. no. Ar 37050. × 0.8.

Fig. 6. Inclomplete hypostome and part of cephalic doublure. 4a*α*. Muggerudkleiva, Eiker—Sandsvær. Coll. L. Størmer, 1925—27. P.M.O. no. 60541. × 0.8.

Fig. 7. Small pygidium. 4a*α*. Between Hagabukta and Sjøstrand, Asker. (Associated with *O. striolata corrugata* n. subsp.) Coll. G. Henningsmoen, 1958. P.M.O. no. 72138. × 0.8.

PLATE 1

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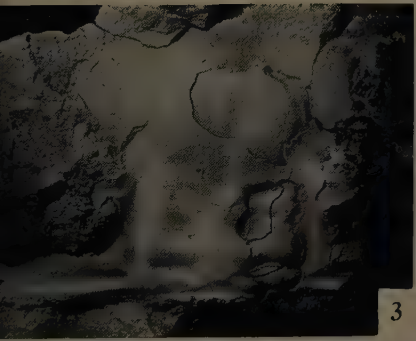
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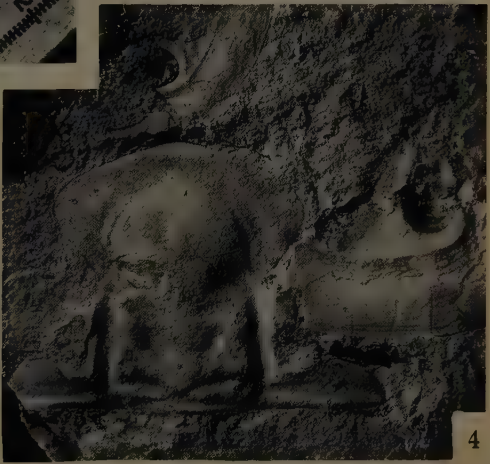
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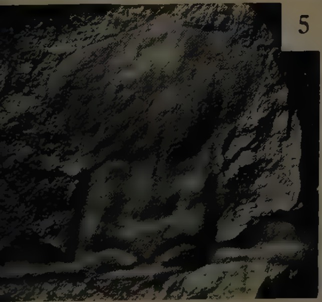
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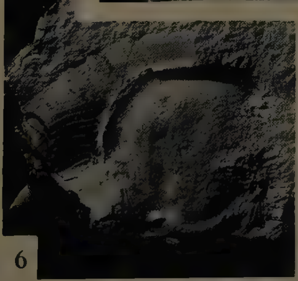
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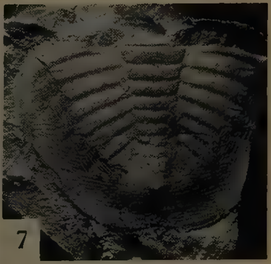
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PLATE 2

All natural size.

Ogygiocaris dilatata (BRÜNNICH, 1871).

Fig. 1. Latex cast of part of cephalon. 4a*α*. Muggerudkleiva, Eiker—Sandsvær. Coll. L. Størmer, 1925—27. P.M.O. no. 60457. × 1.

Fig. 2. Free cheek showing doublure. 4a*α*. Muggerudkleiva, Eiker—Sandsvær. Coll. L. Størmer, 1925—27. P.M.O. no. 60551. × 1.

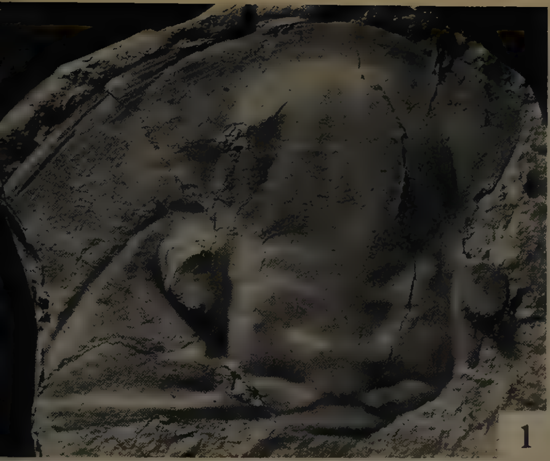
Fig. 3. Latex cast of pygidium. 4a*α*. Muggerudkleiva, Eiker—Sandsvær. Coll. L. Størmer, 1925—27. P.M.O. no. 72144. × 1.

Fig. 4. Pygidium. 4a*α*. Muggerudkleiva, Eiker—Sandsvær. Coll. L. Størmer, 1925—27. P.M.O. no. 60471. × 1.

Fig. 5. Pygidium. Terrace lines on test less transverse than in most specimens. 4a*α*. Muggerudkleiva, Eiker—Sandsvær. Coll. L. Størmer, 1925—27. P.M.O. no. 72143b. × 1.

Fig. 6. Pygidium. The right side shows well the undulating paradoublural line. 4a*α*. Muggerudkleiva, Eiker—Sandsvær. Coll. L. Størmer, 1925—27. P.M.O. no. 72103. × 1.

PLATE 2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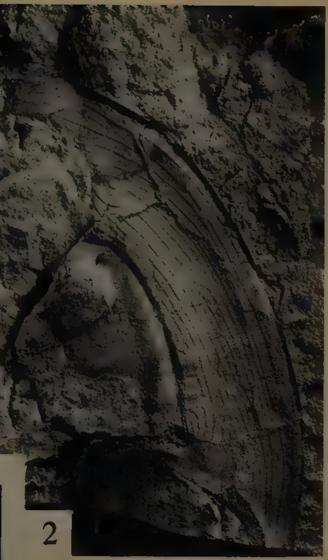
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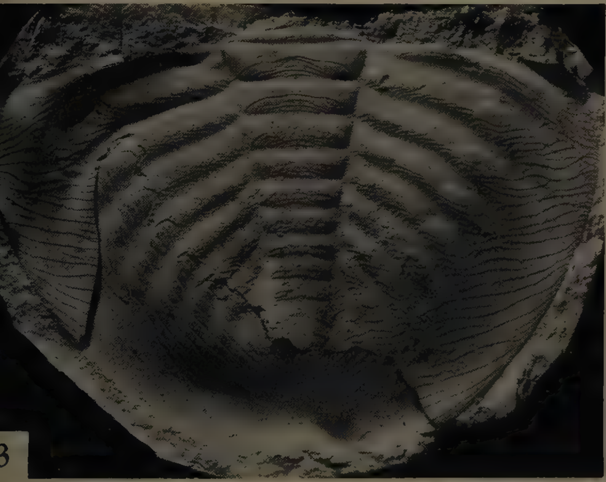
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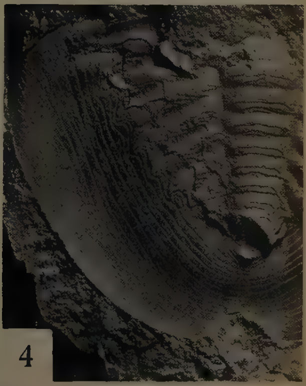
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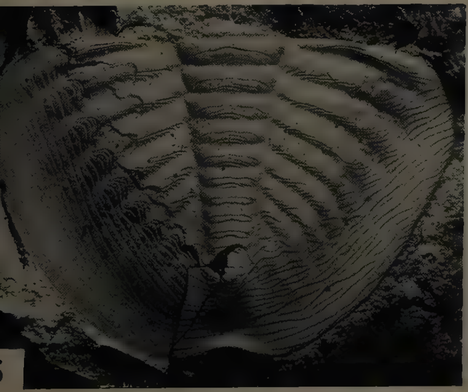

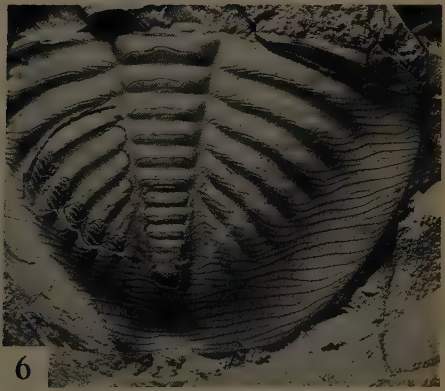
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PLATE 3

Ogygiocaris striolata corrugata n. sp. & subsp.

Fig. 1. Cranidium. Loose limestone lens with calcite fillings, 4aα. Elnestangen, Asker. Coll. G. Henningsmoen, 1959. P.M.O. no. 72131. × 1.

Fig. 2. Fragmentary pygidium. Same lens as the specimen in fig. 1. P.M.O. no. 72120. × 1.

Fig. 3. Fragmentary pygidium, holotype. Limestone lens, 4aα, 4.60 m below continuous limestone bed in the section in text fig. 3. Between Hagabukta and Sjøstrand, Asker. Coll. G. Henningsmoen, 1959. P.M.O. no. 72134. × 1.

Fig. 11. Detail of pygidium in fig. 3. × 3.

Ogygiocaris striolata striolata n. sp. & subsp.

Fig. 4. Fragmentary free cheek. 4aα. Limestone lens 1.0 m below continuous limestone bed in section in text fig. 3. Between Hagabukta and Sjøstrand, Asker. Coll. G. Henningsmoen, 1958. P.M.O. no. 72112. × 1.

Fig. 5. Fragmentary cranidium. From same lens as the specimen in fig. 4. P.M.O. no. 72115. × 1.

Fig. 6. Pygidium. Light from behind. From same lens as the specimen in fig. 4. P.M.O. no. 72114. × 1.

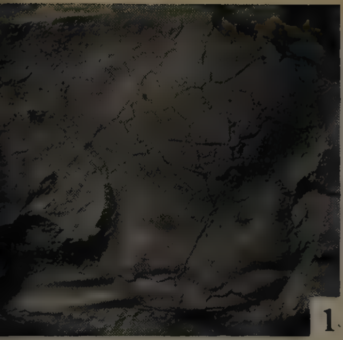
Fig. 7. Hypostome. 4aα. Limestone lens ca. 1 m below lowest continuous limestone bed. Elnestangen, Asker. Coll. G. Henningsmoen, 1959. P.M.O. no. 72104. × 1.

Fig. 8. Pygidium (*holotype*) from same lens as the specimen in fig. 4. P.M.O. no. 72108. × 1.

Fig. 9. Pygidium. 4aα. Fornebu, Bærum, Oslo-Asker. Coll. W. Werenskiold, 1910. P.M.O. no. 3750. × 1.

Fig. 10. Detail of pygidium in fig. 8. × 3.

Plate 3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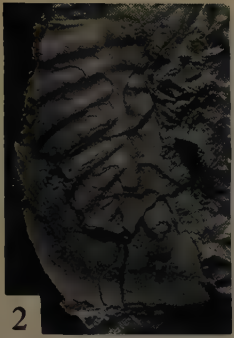
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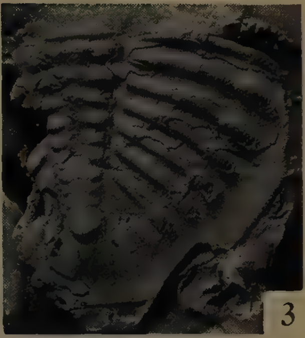
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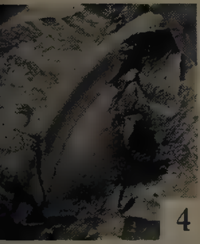
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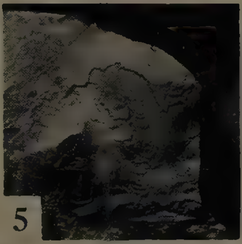
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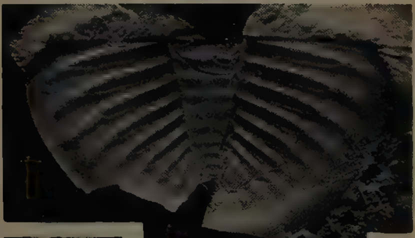
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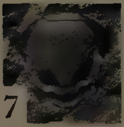
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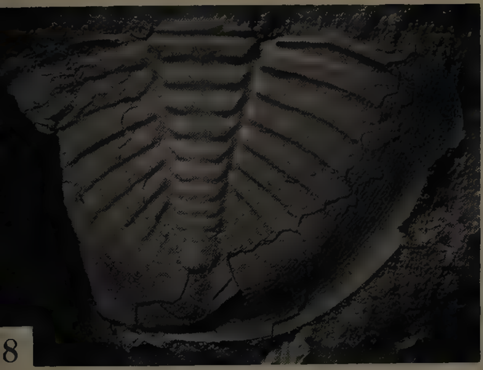
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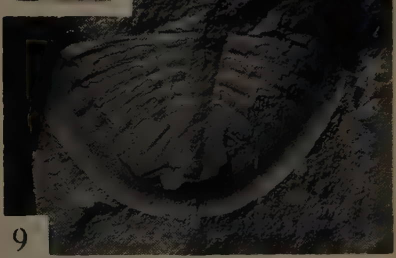
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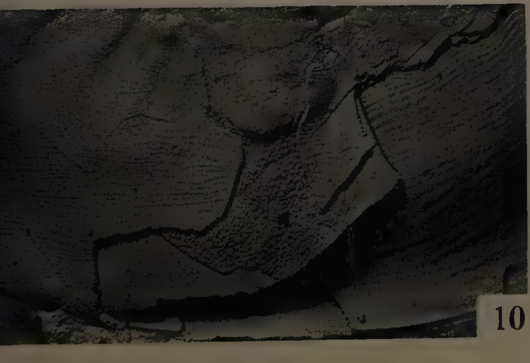
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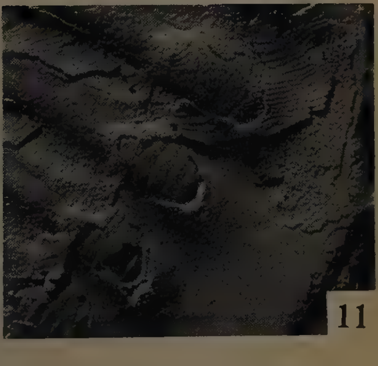
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PLATE 4

Ogygiocaris sarsi sarsi ANGELIN, 1872.

Fig. 1. Disconnected dorsal shield, *lectotype*. 4aα, evidently 4aα_3. Hjortnestangen, Oslo. Coll. M. Sars. P.M.O. no. 20287. × 1.

Fig. 2. Latex cast of counterpiece of lectotype. The specimen appears to be somewhat forelengthened. P.M.O. no. 20288. × 1.

Fig. 3. Pleuron, partly showing doublure. 4aα. Vekkopp, Bygdøy, Oslo. Coll. P. Størmer. P.M.O. no. 53298. × 1.8.

Fig. 4. Hypostome, slightly forelengthened. 4aα. Håkavik, Asker. Coll. G. Holm, 1879. Figured by LINDSTRÖM, 1901, pl. 5, figs. 27–28. RM. no. Ar 37135. × 1.

Fig. 5. Sample showing two deformed pygidia, oriented at right angles to each other. The left pygidium (P.M.O. no. 20286a) with exaggerated width (W-form), the right pygidium (no. 20286b) with exaggerated length (L-form). 4aα_3. Huk, Bygdøy, Oslo. × 1.

Fig. 6. Side view of eye. 4aα. Hjortnestangen, Oslo. The old collection. P.M.O. no. 56320. × 4.5.

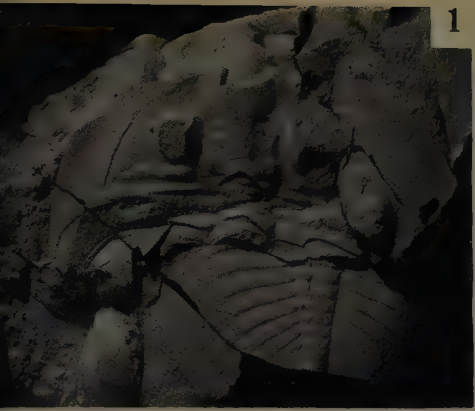
Fig. 7. Small pygidium. 4aα. Huk, Bygdøy, Oslo. The old collection. P.M.O. no. 3647. × 1.

Fig. 8. Cranidium. 4aα_3. Huk, Bygdøy, Oslo. Coll. Excursion, 1907. P.M.O. no. 3647. × 1.9.

Fig. 9. Same cranidium as in fig. 8. × 1.

Fig. 10. Pygidium. 4aα. Steilene, Oslo-Asker. Coll. J. Kiær, 1920. P.M.O. no. 3681. × 1.

PLATE 4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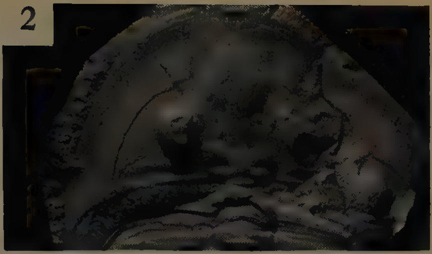
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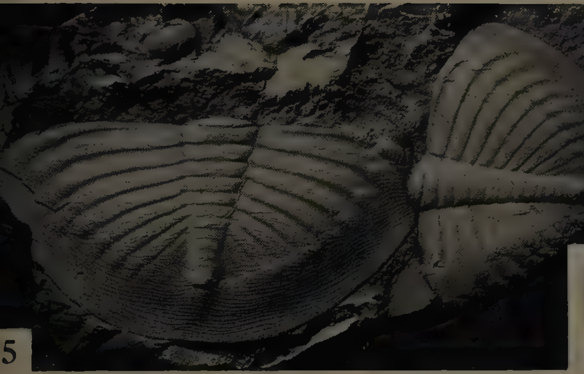
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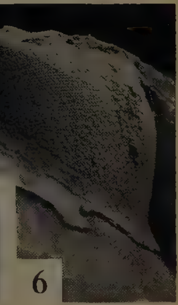
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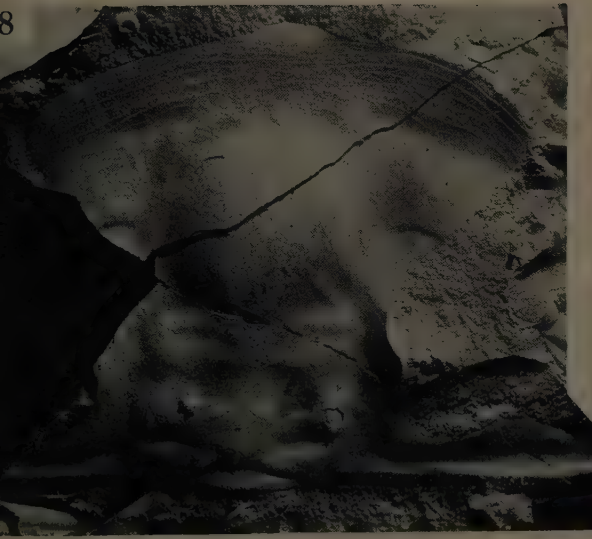
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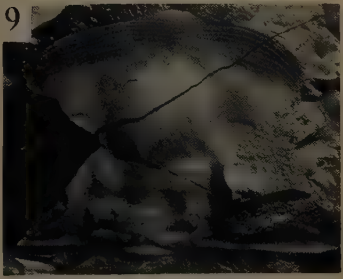
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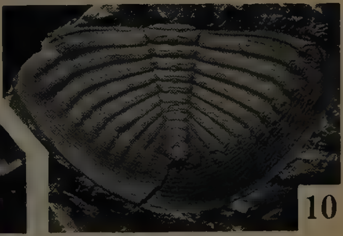
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PLATE 5

Ogygiocaris sarsi regina n. subsp.

Fig. 1. Large pygidium, probably of this subspecies. Probably from 4a*α* in Toten. P.M.O. no. 72117. × 1.

Fig. 2. Small pygidium. Ogygiocaris shale. Hovindsholm, Helgøya, Hamar—Nes. Coll. O. Holtedahl, 1906. P.M.O. no. 36730. × 2.

Fig. 3. Free cheek with spine brooken off. Ogygiocaris shale. Hovindsholm, Helgøya, Hamar—Nes. Coll. O. Holtedahl, 1906. P.M.O. no. 36786. × 1.

Fig. 4. Small cranidium. Ogygiocaris shale. Hovindsholm, Helgøya, Hamar—Nes. Coll. G. Henningsmoen, 1957. P.M.O. no. 72099. × 1.

Fig. 5. Cranidium. Ogygiocaris shale. Hovindsholm, Helgøya, Hamar—Nes. Coll. O. Holtedahl, 1906. P.M.O. no. 36790. × 1.

Fig. 6. Cranidium. Ogygiocaris shale. Hovindsholm, Helgøya, Hamar—Nes. Coll. G. Henningsmoen, 1959. P.M.O. no. 72082. × 1.

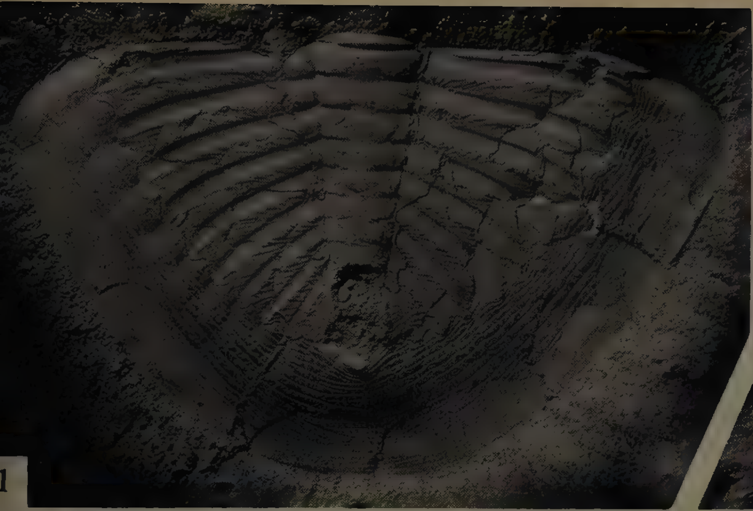
Fig. 7. Dorsal shield, *holotype*. Ogygiocaris shale, Toten. Collector unknown. no. 72090. × 0.95.

Fig. 8. Cephalon. Ogygiocaris shale. Hovindsholm, Helgøya, Hamar—Nes. Coll. O. Holtedahl, 1906. P.M.O. no. 36722. × 1.

Ogygiocaris sarsi lata HADDING, 1913.

Fig. 9. Cephalon. Ogygiocaris shale. Andersön, Jämtland, Sweden. Coll. K. Fahlander & E. Julin, 1929. P.I.U. no. ar 1046.

PLATE 5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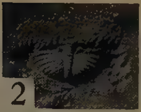
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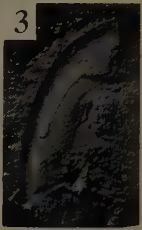
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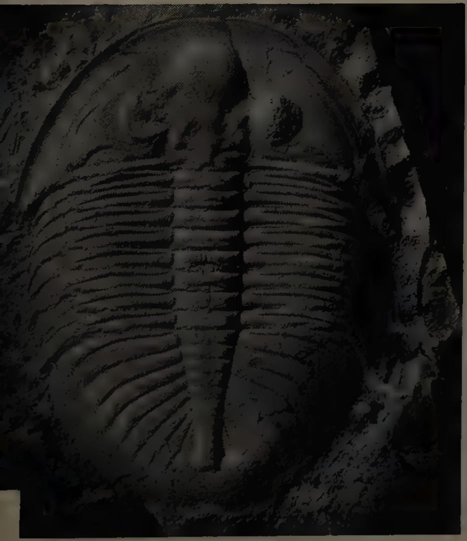

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PLATE 6

Ogygiocaris sarsi delicata n. subsp.

Fig. 1. Cranidium, *holotype*. Helgøya, Hamar—Nes. Coll. W. C. Brøgger, 1881. P.M.O. no. 36673. × 1.

Fig. 2. Free cheek. Hovindsholm, Helgøya, Hamar—Nes. Coll. O. Holtedahl, 1906. P.M.O. no. I 1418b.

Fig. 3. Small cranidium. Kolbo, N. Toten. Coll. G. Holm, 1897. RM. no. Ar 37119. × 2.

Fig. 4. Tiny cranidium. Main road north of Hval, Ringerike. Coll. Th. Munster, 1892. P.M.O. no. 33067. × 2.

Fig. 6. Pygidium. Hovindsholm, Helgøya, Hamar-Nes. Coll. O. Holtedahl, 1906. P.M.O. no. I 1418a. × 1.

Fig. 7. Pygidium. Hovindsholm, Helgøya, Hamar—Nes. Coll. W. C. Brøgger, 1881. P.M.O. no. 36675. × 1.

Fig. 8. Two pygidia. Hovindsholm, Helgøya, Hamar—Nes. Coll. G. Henningsmoen, 1957. P.M.O. no. 72091. × 1.

Fig. 9. Pygidium. Sterudstranda, Hamar—Nes. Coll. S. Skjeseth, 1950. P.M.O. no. 72071. × 2.

Fig. 10. Tiny pygidium (counterpiece). Sterudstranda, Hamar—Nes. Coll. S. Skjeseth, 1950. P.M.O. no. 72072. × 2.

Fig. 11. Hypostome. Hovindsholm, Helgøya, Hamar—Nes. Coll. W. Dean, F. Hagemann, & G. Henningsmoen, 1954. P.M.O. no. 72094. × 2.

Fig. 12. Pygidium. Sterudstranda, Hamar—Nes. Coll. S. Skjeseth, 1954. P.M.O. no. 72071. × 2.

Ogygiocaris sarsi regina n. subsp.

Fig. 5. Thorax and pygidium. Ogygiocaris shale. Hovindsholm, Helgøya, Hamar—Nes. Coll. G. Henningsmoen, 1957. P.M.O. no. 72098. × 1.

Ogmasaphus multistriatus n. sp.

Fig. 13. Pygidium, *holotype*. (Associated with the cranidium in fig. 16.) Ogygiocaris shale. Storhamar, Hamar—Nes. Coll. ?, 1883. P.M.O. no. 36822a. × 1.

Fig. 14. Pygidium. 4a? Kilen, Fornebu, Bærum, Oslo—Asker. Coll. W. Werenskiold, 1907. P.M.O. no. 6007. × 1.

Fig. 15. Part of cephalon. Ogygiocaris shale. Helgøya, Hamar—Nes. Coll. O. Holtedahl, 1907. P.M.O. no. 21931. × 2.5.

Fig. 16. Small cranidium. Ogygiocaris shale. Storhamar, Hamar—Nes. Coll. ?, 1883. P.M.O. no. 36822b. × 2.4.

Fig. 17. Pygidium, same species? Ampyx limestone (4aβ). Road section at Gyssestad, Oslo—Asker. Coll. A. Heintz, 1933. P.M.O. no. 40345. × 1.

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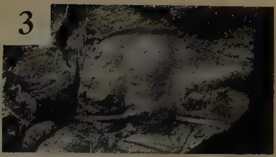

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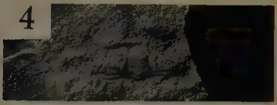

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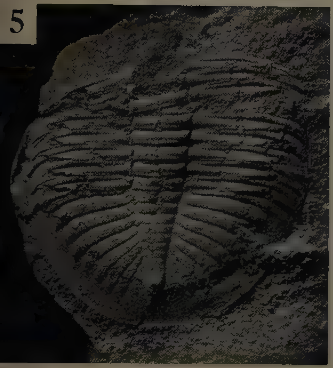

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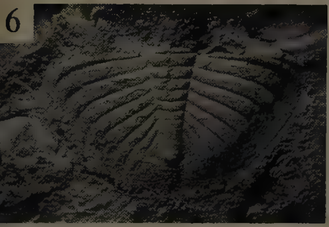

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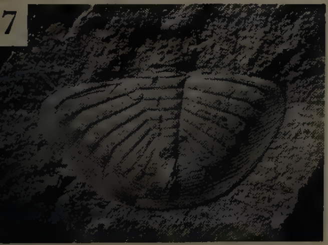

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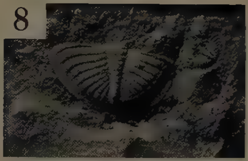

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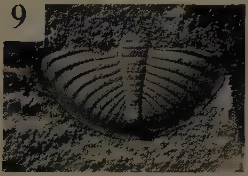

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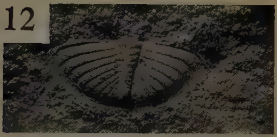

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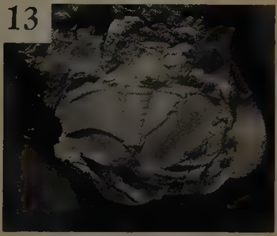

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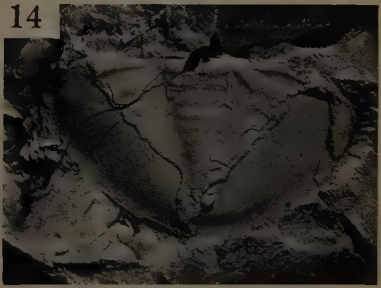

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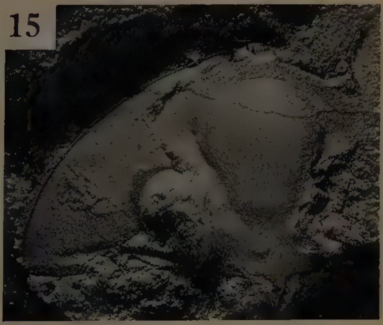

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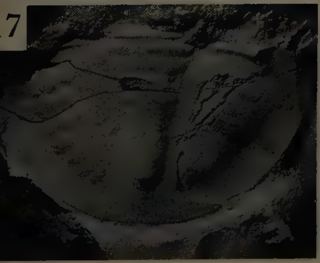


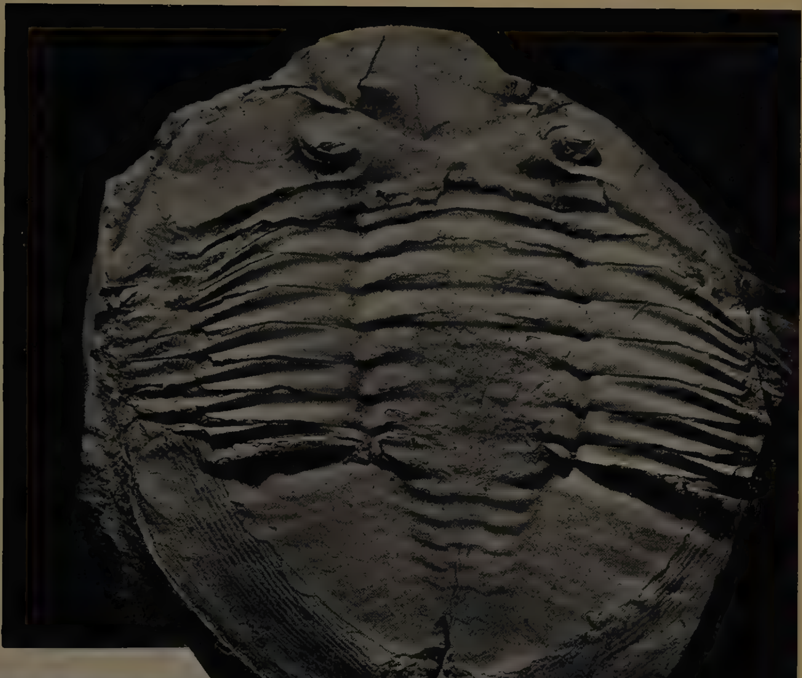
PLATE 7

Asaphus (*Neoasaphus*) *heintzi* n. sp.

Fig. 1. Dorsal shield, *holotype*. Lower Chasmops shale (4bα). Road section, State Road no. 40 at Gyssestad, Oslo—Asker. Coll. A. Heintz. 1932. P.M.O. no. 72073. × 1.

Fig. 2. Dorsal shield without free cheeks. Same horizon, locality, and collector. P.M.O. no. 55969. × 0.8.

Fig. 3. Free cheek. Same horizon, locality, and collector. P.M.O. no. 18899. × 1.



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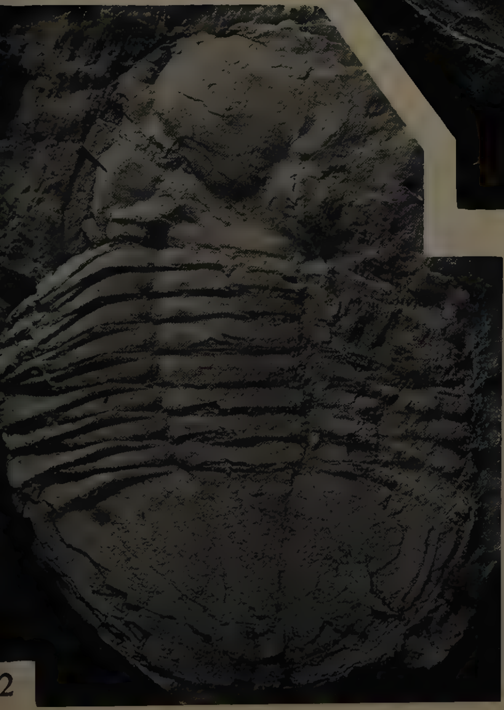

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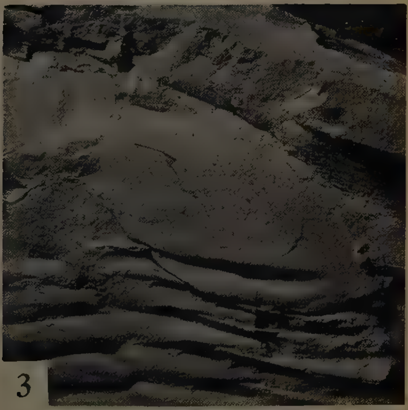

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PLATE 8

All ca. natural size.

Asaphus (Neoasaphus) ludibundus TÖRNQUIST, 1884.

Figs. 1—3. Dorsal shield. Dorsal views of cephalon, entire specimen (with somewhat drooping cephalon and pygidium), and pygidium. Probably Ampyx limestone (4aβ). Fornebu, Bærum, Oslo—Asker. Coll. ?, 1935. P.M.O. no. 58932. × 1.

Fig. 4. Enrolled specimen showing concave (from above) cephalic doublure. Horizon unknown. South end of Persteilene, Oslo—Asker. Coll. ? P.M.O. no. 6165. × 1.

Fig. 5. Cranidium of form with narrow preocular fixigenal areas. 4aβ or 4bα. West side of Røysetangen, Ringerike. Coll. J. Kiær, 1913. P.M.O. no. 7464. × 1.

Asaphus (Neoasaphus) cf. *ludibundus* TØRNQUIST, 1884.

Fig. 6. Dorsal shield. Cephalopod shale. Mjøsa districts (locality unknown). Coll. ? P.M.O. no. 36941. × 1.

PLATE 8

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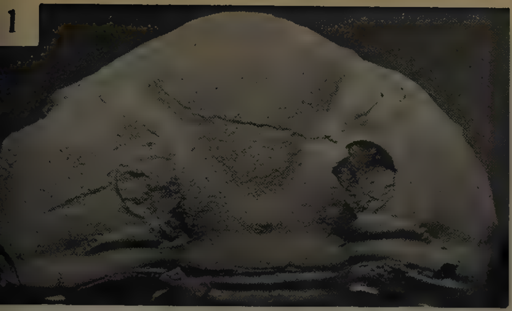

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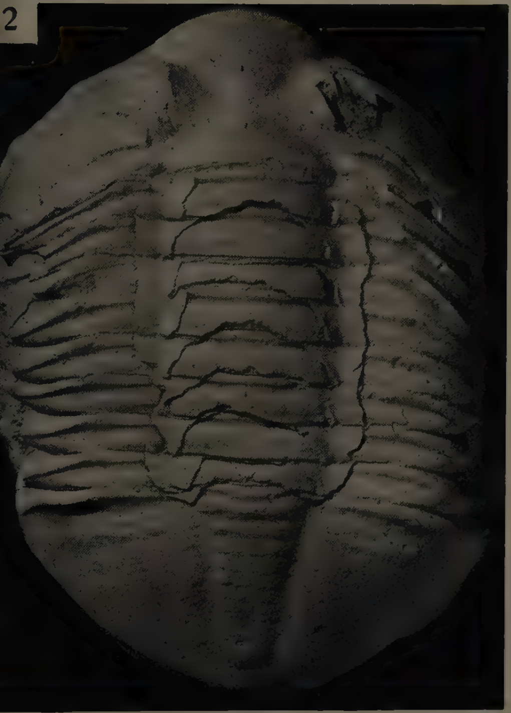

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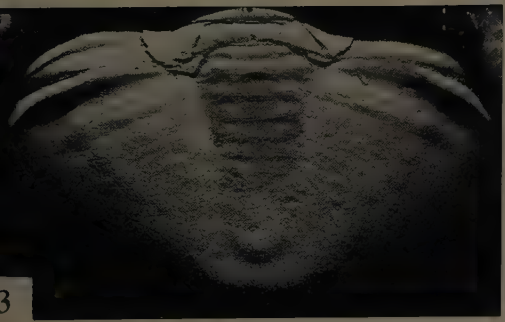

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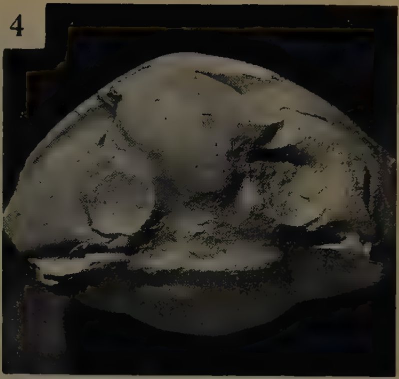

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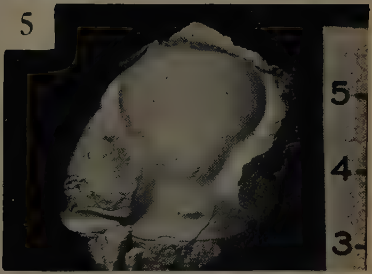

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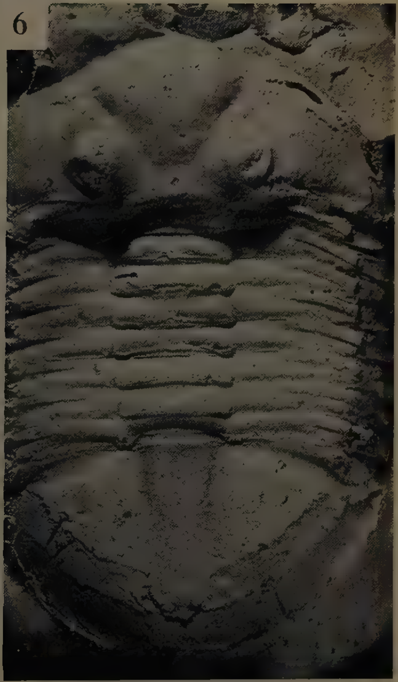


PLATE 9

Ogmasaphus jaanussoni n. sp.

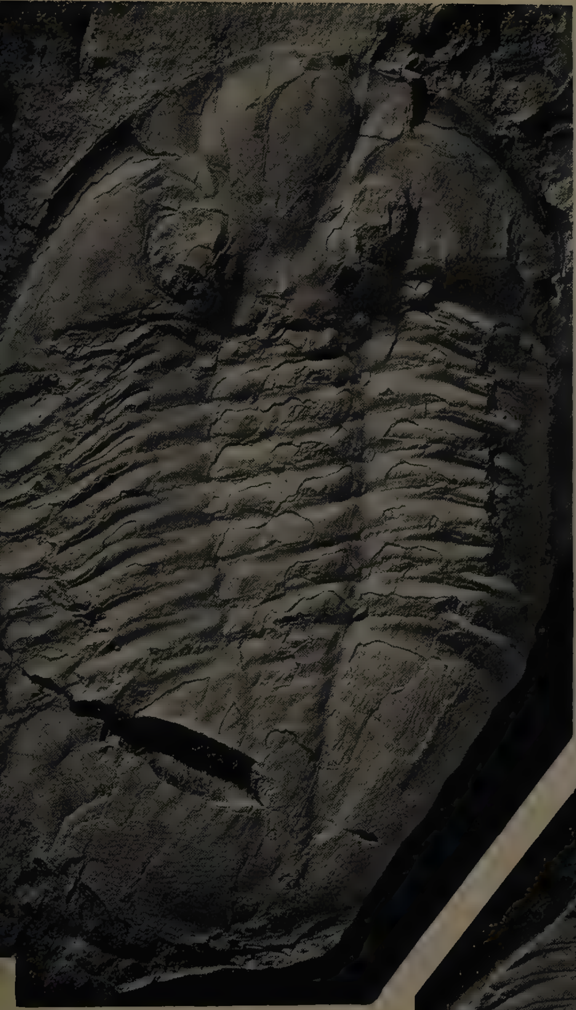
Fig. 1. Dorsal shield, *holotype*. Horizon unknown. Ruseløkkveien, Oslo. Coll. ? P.M.O. no. 61519 . × 1.

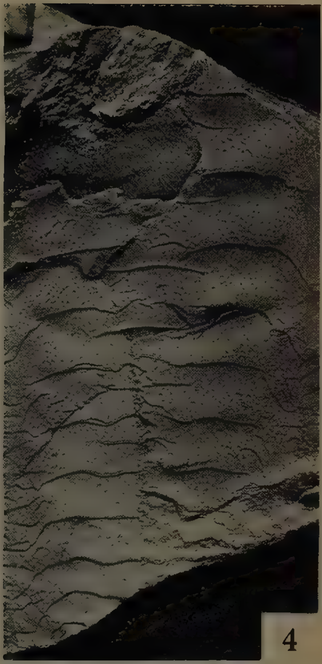
Fig. 2. Conspecific? pygidium. 4a? Building site of Rådhuset (City Hall) in Oslo. Coll. A. Heintz. 1933. P.M.O. no. 56580. × 1.

Fig. 3. Dorsal shield. Horizon? Oslo. A.G. Strøm dedit., 1891. P.M.O. no. 20289. × 1.

Pseudoasaphus limatus JAANUSSON, 1953.

Fig. 4. Detail of pygidial axis, showing pits on the outer surface. Horizon? Fornebu Air Field, Bærum, Oslo—Asker. Coll. Kristiansen, 1935. P.M.O. no. 72067. × 2.





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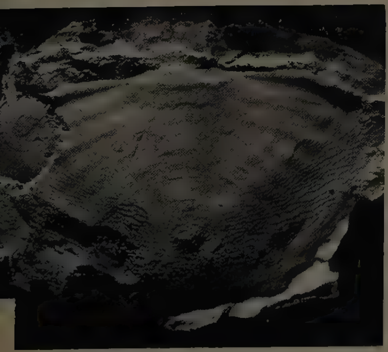

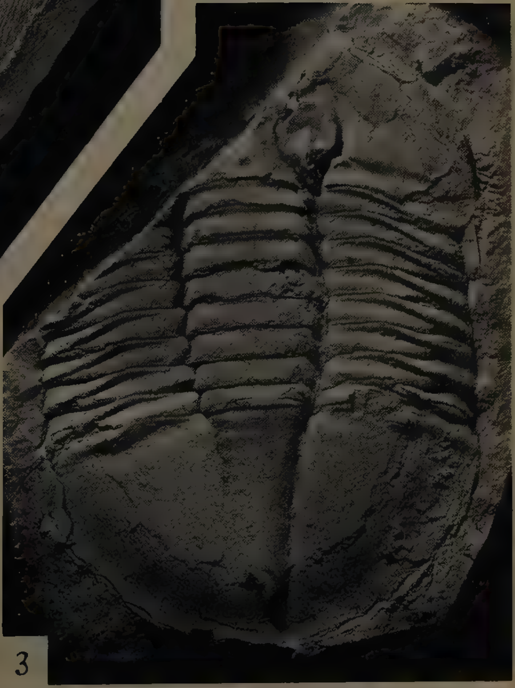

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PLATE 10

Ogmasaphus kiaeri n. sp.

Fig. 1. Detail of dorsal shield of this species (?), showing cephalic and thoracic doublure and genal angle. 4a—b? Sarpsborggata, Oslo. Coll. S. Rønning, 1932. P.M.O. no. 58932. × 1.

Fig. 2. Cephalon. 4aβ. Holmen, Vollen, Asker. Coll. G. Henningsmoen, 1959. P.M.O. no. 72057. × 1.

Figs. 3—4. Cephalon and pygidium of dismembred enrolled dorsal shield. 4aβ. Holmen, Vollen, Asker. Coll. G. Henningsmoen, 1959. P.M.O. nos. 72063—64. × 1.

Fig. 5. Cranidium. 4aβ. Small peninsula on Bygdøy, opposite Skarpsno, Oslo. Coll. G. Henningsmoen, 1941. P.M.O. no. 63460. × 1.

Fig. 6. Pygidium with parts of outer test preserved. 4aβ. Holmen, Vollen, Asker. Coll. G. Henningsmoen, 1959. P.M.O. no. 72058. × 1.

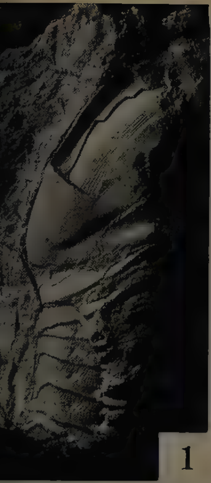
Fig. 7. Exfoliated pygidium. 4aβ? Fornebu Air Field, Bærum, Oslo—Asker. Coll. ?, 1935. P.M.O. no. 58929. × 1.

Fig. 8. Exfoliated pygidium, also showing some of the doublure. 4aβ. Road section, State Road no. 40 at Gyssestad, Oslo—Asker. Coll. A. Heintz, 1933. P.M.O. no. 40341. X 1.

Fig. 9. Hypostome. 4aβ. Holmen, Vollen, Asker. Coll. G. Henningsmoen, 1959. P.M.O. no. 72056. × 1.

Fig. 10. Pygidium showing most of the doublure. Outer test surface present only at anterior end of axis. 4aβ. Terneskjær, Oslo—Asker. Coll. J. Kiær, 1898. P.M.O. no. 4110. × 2.8.

Figs. 11—12. Enrolled specimen, somewhat dismembered. *Holotype*. Outer test missing, except in small patches. 4aβ. S. Kojatange, Asker. Coll. J. Kiær, 1898. P.M.O. no. 19112. × 1.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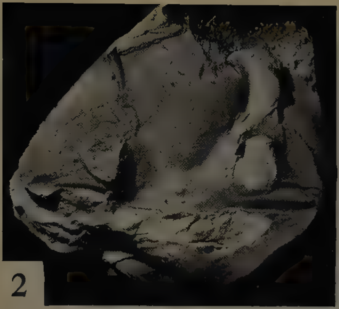
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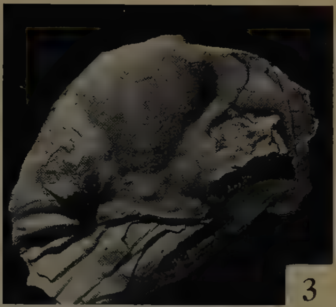
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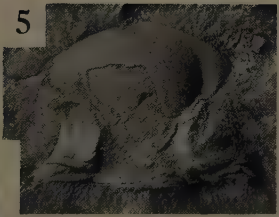
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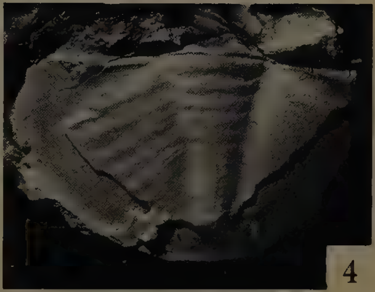
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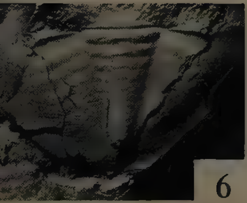
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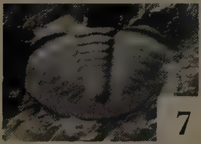
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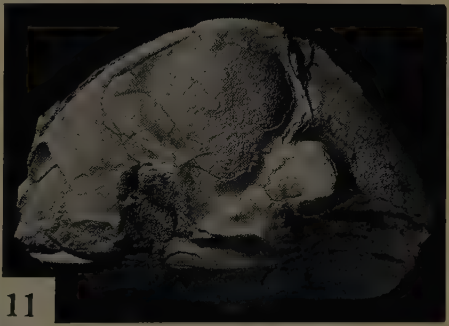
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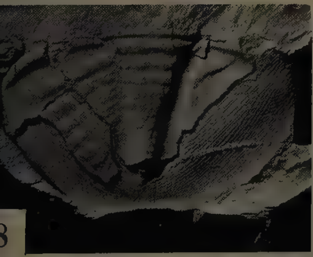
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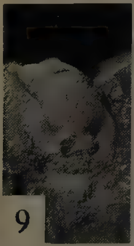
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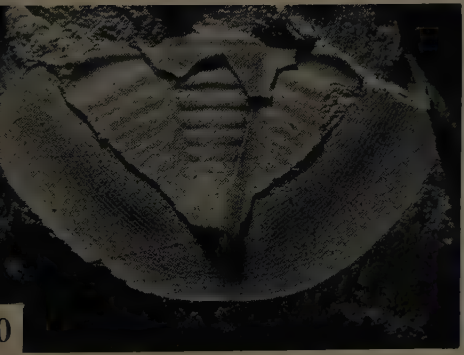
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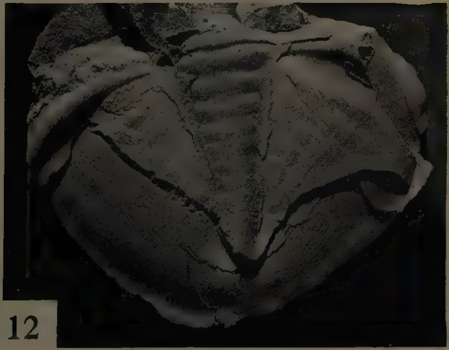
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PLATE 11

All natural size.

Ogmasaphus stoermeri n. sp.

Fig. 1. Dorsal shield, *holotype*. 4a*α*. Teigen slate pit, Eiker. Coll. M. Langberg; S. Swensen dedit., 1892. P.M.O. no. 5684. × 1.

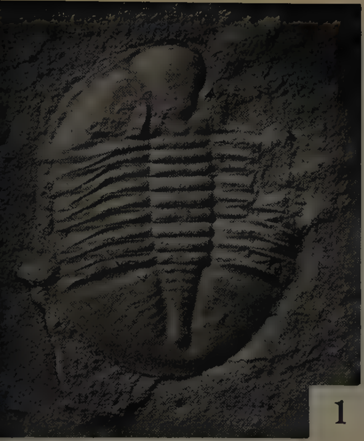
Fig. 2. Dorsal shield. Part of glabella missing, showing incomplete hypostome in situ. 4a*α*. Teigen slate pit, Eiker. Coll. M. Langberg; S. Swensen dedit., 1892. P. M. O. no. 4682. × 1.

Fig. 3. Dismembered cephalon, showing genal angle of right free cheek. 4a*α*. Muggerudkleiva, Eiker—Sandsvær. Coll. L. Størmer, 1925—27. P.M.O. no. 60390. × 1.

Fig. 4. Hypostome. Same horizon, locality, and collector. P.M.O. no. 60390b × 1.

Fig. 5. Pygidium. Same horizon, locality, and collector. P.M.O. no. 60379. × 1.

Fig. 6. Unsually large pygidium. Most probably from 4a*α* in Eiker—Sandsvær. P.M.O. no. 72069. × 1.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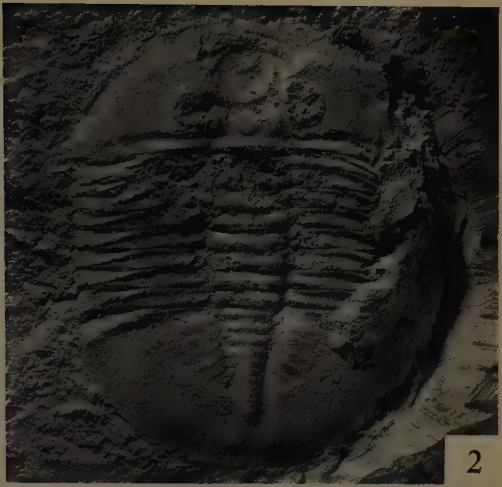
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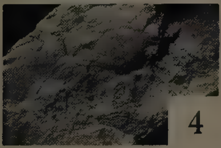
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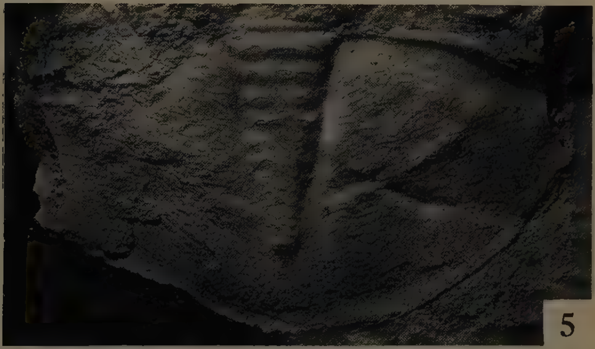
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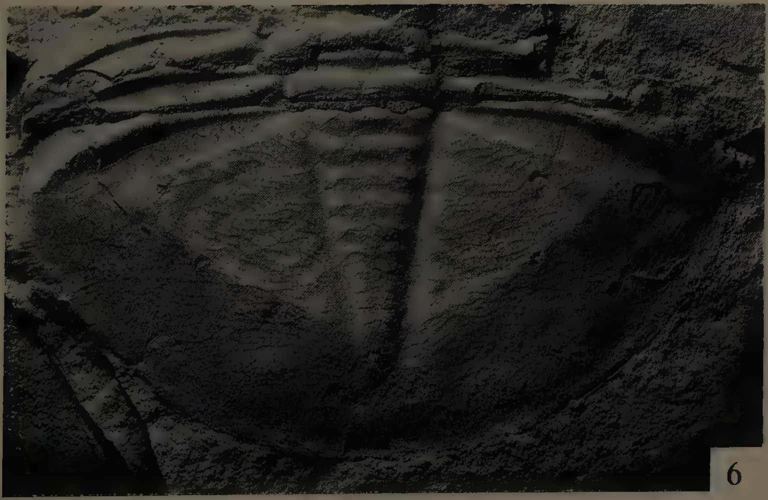
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Plate 12

All natural size.

Pseudomegalaspis patagiata (Törnquist, 1884).

Figs. 1–2. Dorsal shield, showing left genal spine. The pygidium of this specimen was figured by Jaanusson (1953, pl. X, fig. 2), as *P. formosa*. 4aα. Site of Vigeland fountain, Vigeland Park, Oslo. Coll. A. Heintz, 1934. P.M.O. no. 56556. × 1.

Fig. 3. Pygidium showing zone of terrace lines along paradoublural line. 4aα_3. Engerodden, Asker. Coll. N. Spjeldnæs, 1951. P.M.O. no. 72075. × 1.

Fig. 4. Free cheek (genal spine broken off). 4aα_3. Elnestangen, Asker. Coll. G. Henningsmoen, 1959. P.M.O. no. 72079. × 1.

Fig. 5. Pygidium showing terrace lines on various parts of the surface. 4aα_3. Huk, Bygdøy, Oslo. Coll. ?, 1915. P.M.O. no. 20193. × 1.

Fig. 6. Pygidium. Ogygiocaris shale. Ringerike. Coll. J. Kiær. P.M.O. no. 72089. × 1.

Fig. 7. Cranidium. Ogygiocaris shale. Ringerike. Coll. J. Kiær. P.M.O. no. 72083. × 1.

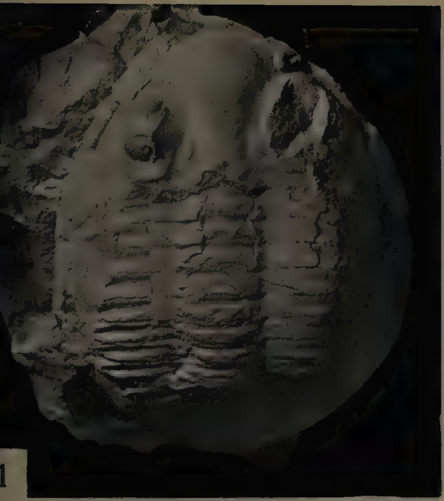
Pseudomegalaspis? sp.

Fig. 8. Dorsal shield. Most probably Cephalopod shale. Storhamar, Hamar–Nes. Coll. N. Johansen; J. Jørgensen dedit., 1898. P. M. O. no. 36832. × 1.

Ogmasaphus sp.

Fig. 9. Pygidium. Cephalopod shale. Hovindsholm, Helgøya, Hamar–Nes. Coll. O. Holtedahl, 1907. P.M.O. no. 72074. × 1.

PLATE 12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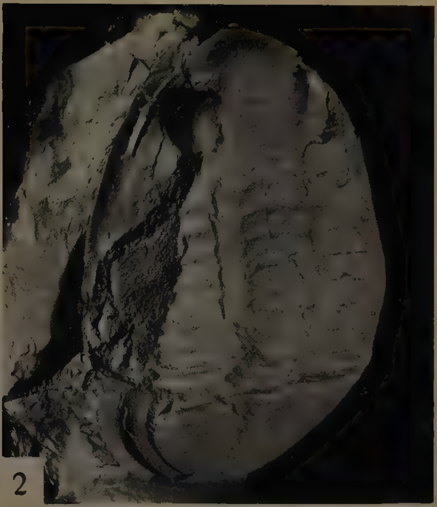
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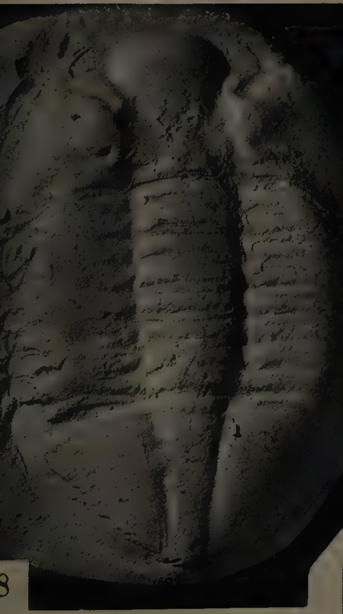
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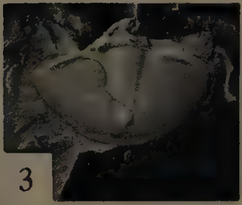
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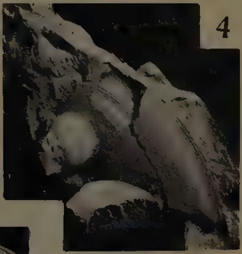
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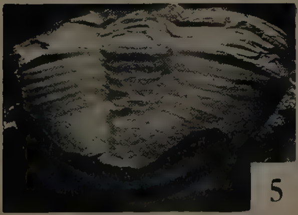
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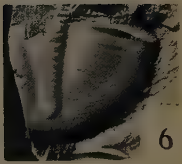
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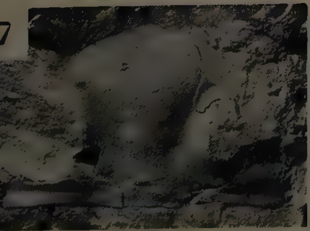
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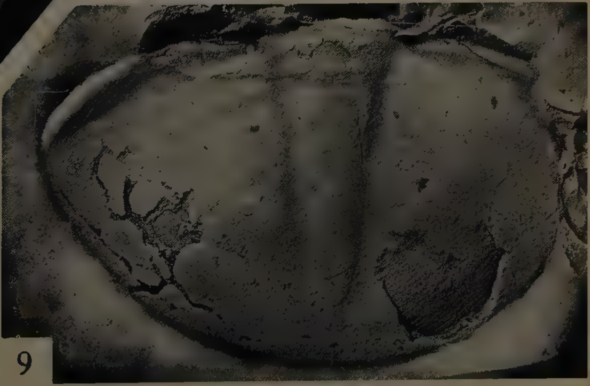
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PLATE 13

All natural size.

Pseudoasaphus limatus JAANUSSON, 1953.

Fig. 1. Pygidium. Oslo region (horizon and locality unknown). P.M.O. no. 20137. × 1.

Fig. 2. Cranidium. 4aβ. Road section, State Road no. 40 at Gyssestad, Oslo—Asker. Coll. A. Heintz, 1933. P.M.O. no. 40355. × 1.

Fig. 3. Hypostome. Same horizon, locality, and collector. P.M.O. no. 40400. × 1.

Fig. 4. Incomplete dorsal shield. 4aβ? Fornebu Air Field, Bærum, Oslo—Asker. Coll. ?, 1935. P.M.O. no. 58911. × 1.

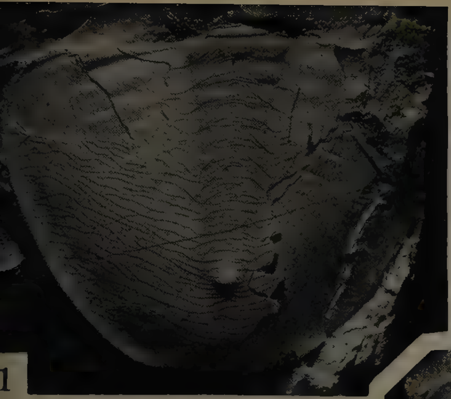
Fig. 5. Incomplete dorsal shield, counterpiece. 4aβ? Fornebu Air Field, Bærum, Oslo—Asker. Coll. 4, 1935. P.M.O. no. 58917. × 1.

Pseudoasaphus sp.

Fig. 6. Pygidium. Coelosphaeridium beds. Shale pit between Tørud and Brattberg, Ringsaker. Coll. W. Dean, F. Hagemann, & G. Henningsmoen, 1954. P.M.O. no. 67290. × 1.

Pseudobasilicus cf. *kuckersianus* (SCHMIDT, 1898).

Fig. 7. Pygidium. 4aβ. Road section, State Road no. 40 at Gyssestad, Oslo—Asker. Coll. A. Heintz, 1933. P.M.O. no. 44246. × 1.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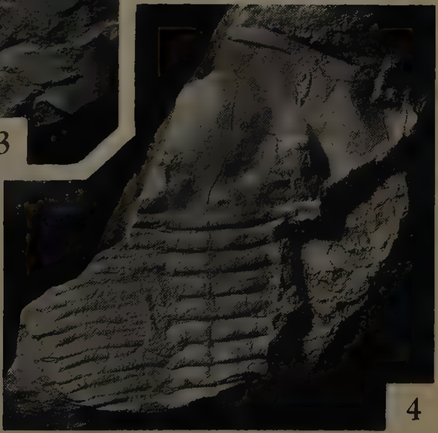
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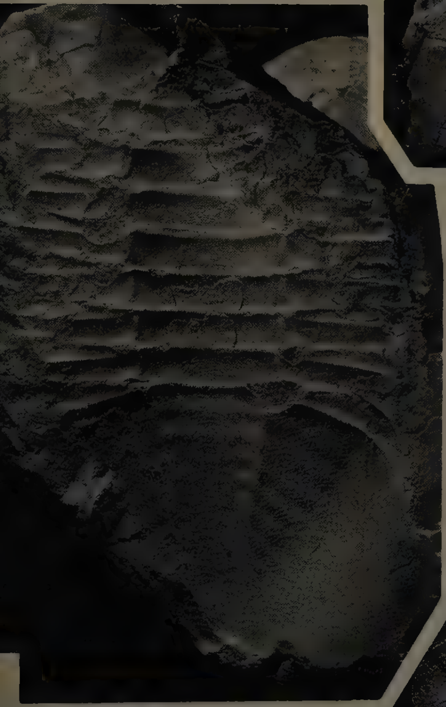

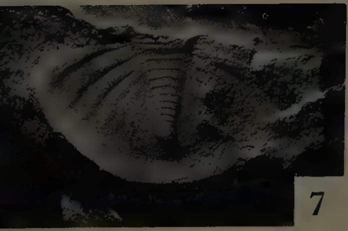
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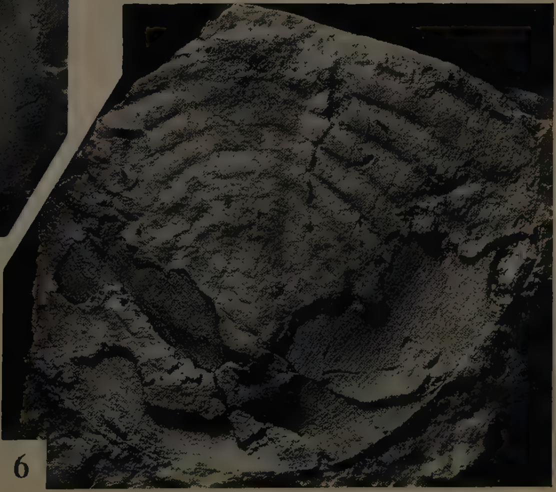
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Plate 14

Pseudobasilicus cf. *kegelensis* (Schmidt, 1898).

Fig. 1. Cranidium. Cyclocrinus beds. Furuberget, Hamar–Nes. Coll. J. Kiær, 1896. P.M.O. no. 38029. × 2.7.

Fig. 4. Cranidium. Same horizon, locality, and collector. P.M.O. no. 38252 × 2.7.

Fig. 8. Conspecific? pygidium. Same horizon, locality, and collector. P.M.O. no. 38253. × 2.6.

Pseudobasilicus? sp.

Fig. 2. Cranidium. Cyclocrinus limestone, Furuberget. Coll. O. Holtedahl, 1907. P.M.O. no. 37918. × 1.

Fig. 3. Cranidium. Same horizon, locality, and collector. P.M.O. no. 37916. × 1.

Isotelus cf. *platyrhachis* Steinhardt, 1874.

Fig. 5. Cranidium. Top of Mjøsa limestone, beds with *Rafinesquina mjoesensis*. North side of northern Bergvika peninsula, Helgøya, Hamar–Nes. Coll. S. Skjeseth and G. Henningsmoen, 1952. P.M.O. no. 67932. × 1.

Fig. 6. Pygidium. Mjøsa limestone. Furuberget, Hamar–Nes. Coll. J. Kiær, 1896. P.M.O. no. 22023. × 1.

Fig. 7. Pygidium. Mjøsa limestone. Furuberget, Hamar–Nes. Coll. J. Kiær, 1922. P.M.O. no. 22057. × 2.6.

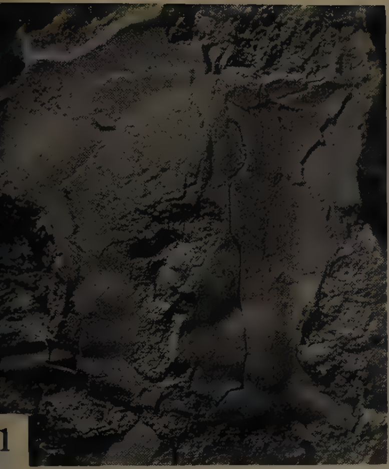
Asaphus (*Neoasaphus?*) sp. A.

Fig. 9. Pygidium. Encrinite limestone. Ås at Frierfjorden, Skien–Langesund. Coll. W. C. Brøgger, 1881. P. M. O. no. 8548. × 1.

Asaphus (*Neoasaphus?*) sp. B.

Fig. 10. Pygidium. Upper Chasmops limestone (4bδ). Nakkholmen, Oslo–Asker. Coll. J. Kiær excursion, 1916. P.M.O. no. 5338. × 2.7.

Plate 14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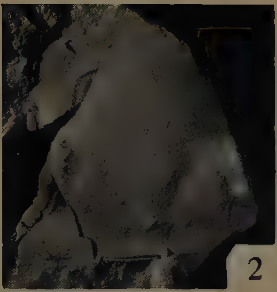
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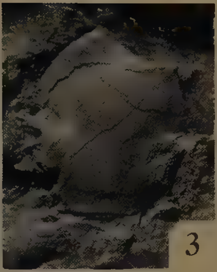
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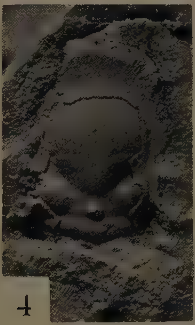
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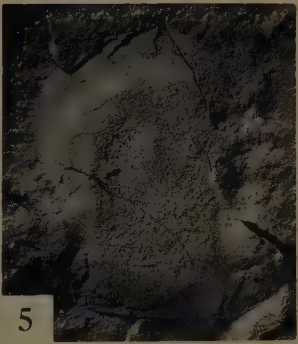
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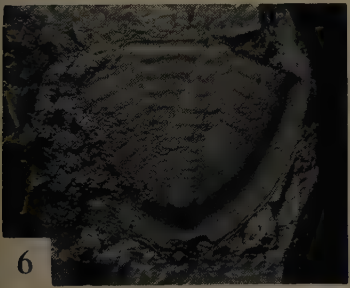
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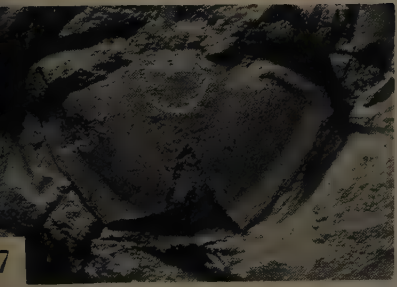
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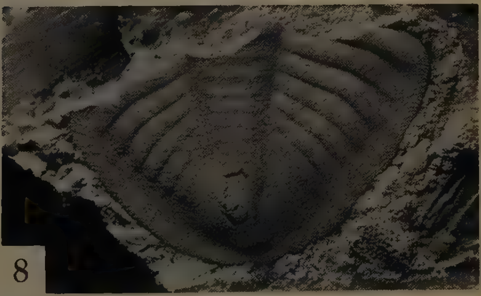
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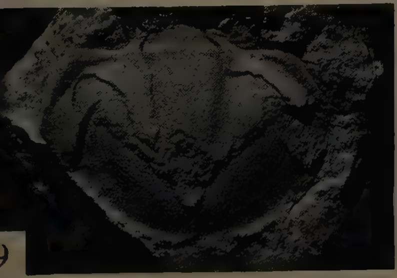
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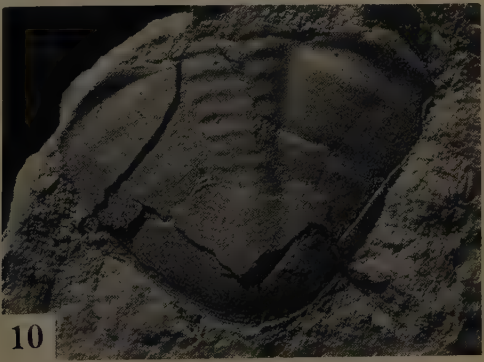
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THE SPECIES
STREPTIS MONILIFERA (M'COY)

By
A. D. Wright
(Queen's University, Belfast).

CONTENTS

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Abstract: The Lower Llandovery form *Streptis monilifera altosinuata* Holtedahl from Asker, Norway, is redescribed biometrically and a comparison with the Ashgillian *S. monilifera* (M'Coy) from Kildare, Ireland, shows the two to be distinct species. The redescription involves the morphological characters of the exterior together with a description of the muscle scars, previously unknown for the genus.

General Introduction and Acknowledgements.

Whilst engaged in a study of the superfamily Triplesiacea for the forthcoming brachiopod part of the Treatise on Invertebrate Paleontology, the specimens of *Streptis monilifera* (M'Coy, 1846) in the author's collections from the high Ashgillian Chair of Kildare Limestone, Kildare, Ireland, were used to try and determine more about this interesting genus. However, serial sectioning of two specimens proved unsatisfactory due to recrystallization of their interiors, and rather than risk more specimens, as complete shells are not common, the author decided to see if the Norwegian subspecies *Streptis monilifera altosinuata* Holtedahl, 1916, would furnish better results.

This material has turned out to be in a much better state of preservation, enabling Professor Holtedahl's original description to be enlarged upon, and the use of a statistical approach has given a more precise determination of the relationship between the Norwegian and the Irish forms. The Norwegian specimens are from the Lower Llandovery (6a—b), about 21—22 m above stage 5b of Konglungen, Asker, in the Oslo region.

I am indebted to Dr. Gunnar Henningsmoen for providing me with a generous quantity of this good material. I also wish to thank Professor A. Williams for helpful advice and discussion, and for reading the manuscript; Mr. A. G. Brighton of the Sedgwick Museum, Cambridge, Mr. M. V. O'Brien of the Irish Geological Survey, Dublin, and Mr. J. D. D. Smith of the British Geological Survey and Museum, London, for lending me the specimens of S. *monilifera* (M'Coy) from the collections in their care to help swell my own material.

Biometrical Introduction.

Nature of material. — The Asker material was in the form of complete shells, in a well preserved state so that at least fifty measurements could be obtained for statistical assessments of a number of characters. On the other hand, although over forty specimens of the Kildare species were available, most of them were single valves; complete shells were relatively few, hence for such measurements as the thickness of the shell, only a small sample could be obtained. For certain measurements, e.g. length against width of the shell, use was made of the fact that the growth lines (especially well marked in *Streptis* by the concentric frills, or when these are broken off, the frill bases) register the true shape of the shell at that particular stage of development.

The measurements. — As many as possible of the following twelve measurements were taken on each specimen:

(a) Maximum length of the ventral valve. This was not, however, used in the analysis as the dorsal length proved to be more convenient (Fig. 1A).

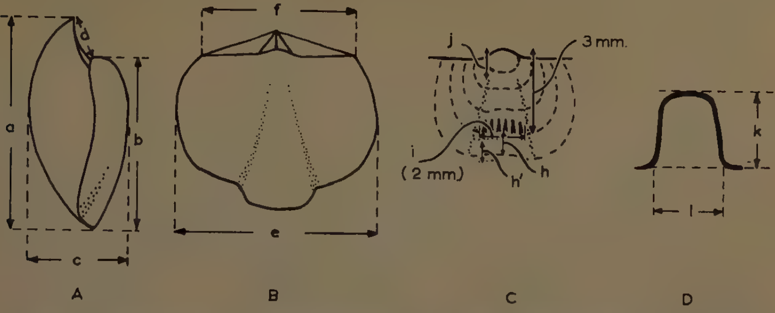

Fig. 1. Positions of measurements on the specimens. (A) Lateral view, (B) dorsal view, (C) the dorsal umbo, (D) median anterior view showing the plication.

(b) Maximum length of the dorsal valve (Fig. 1A).
(c) Maximum thickness of the shell (Fig. 1A).
(d) Length of ventral interarea, measured from the hinge line to the umbo (Fig. 1A).
(e) Maximum width of the shell (Fig. 1B).
(f) Width of the hinge line (Fig. 1B).
(g) Number of frill bases.
(h) Wavelength of the frills at 3 mms. distance from the dorsal umbo, with the specimens orientated so that the shell surface between the frills is perpendicular to the microscope tube. In cases where the 3 mm. distance did not coincide with a frill base, the measurement was taken from the first one anterior to the 3 mm. position, (h'). (Fig. 1C).
(i) Number of radial costae along the median 2 mms. of a frill base on the dorsal valve, measured at a distance of 3 mms. from the umbo, or the first frill anterior to that distance (Fig. 1C).
(j) Distance medially along the dorsal valve at which the plication first appears (Fig. 1C).
(k) Height of plication (Fig. 1D).
(l) Width across base of plication (Fig. 1D).

Measurements a, b, e and g were repeated for a number of growth lines on each valve, orientating the specimen so that the plane of commissure of the valve for any given growth stage was at right angles to the microscope tube.

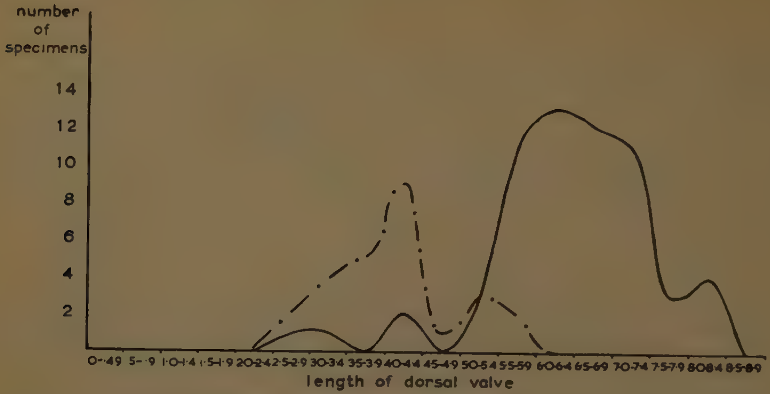

Fig. 2. Length-frequency distribution curves for the samples. The Asker specimens are represented as a continous line, those from Kildare as a broken line.

Application of the measurements. — The frequency distribution for the Asker specimens (Fig. 2), using the dorsal length to represent their size, takes the form of a Gaussian curve with a slight negative skew, and shows the modal length to be just over 6 mms. The Asker specimens were all taken from a small block of limestone shale, all the shells being kept for measurement apart from those discarded through being badly broken. Thus collectors' bias (KERMACK, 1954, p. 388) did not seriously affect the sampling. The presence of a negative skew in what may be considered then as an unbiased sample, instead of the strong positive skew typical of a fossil marine population, indicates that the sample is one which has been sorted by the winnowing effect of currents.

The Kildare specimens (Fig. 2) also show a negative skew, but here the collecting bias is expected to be quite considerable. The modal length of the Kildare specimens is much less than for the Asker ones, and although the size difference between the two samples is significant it carries no taxonomic weight because of the biases just discussed. Instead paired variates are used, so that the "shapes" may be compared rather than the absolute size (KERMACK, p. 392) e.g. length against width, forming the "outline" parameter of the valve.

The statistical procedure used varies somewhat according to the type of parameters. Bivariate analysis was used for valve outline and

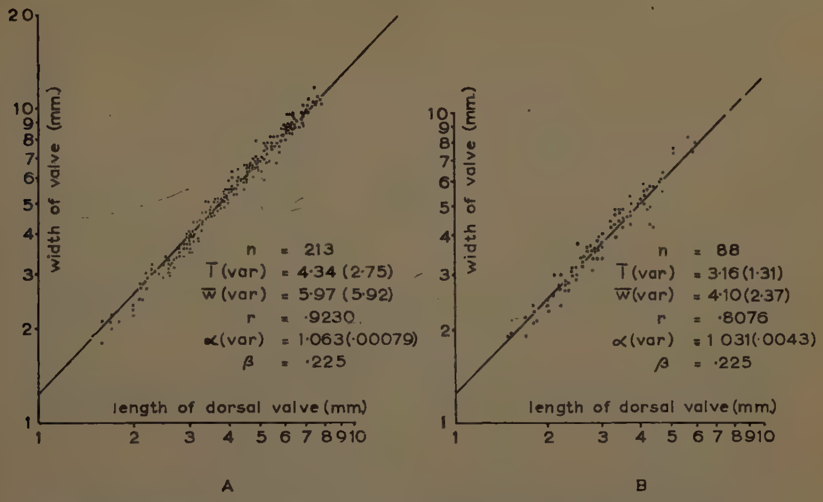

Fig. 3. Scatter diagrams and reduced major axes on log scales of width plotted against dorsal length for (A) the Asker sample (B) the Kildare sample.

convexity, usually involving a test for allometry (Kermack & Haldane, 1950, p. 35), carried out on the larger sample first, as allometric effects may not be apparent in a small sample. When this had been tested, a comparison of growth ratios (a or α) and the "initial growth shape" (b or β) (Kermack, p. 408) was made again using Students' 't' test, to ascertain whether the difference between the two samples was significant. Univariate distributions with continuous variables, e.g. origin of the plication, were also tested by a 't' test, discontinuous variables, e.g. the number of frill bases present on shells, by a 2 × 2 test.

In comparisons of characters displayed by only a small number of the Kildare stock, the Asker sample was reduced to those specimens within the same size range as the Irish one. Nonetheless, statistics for the full Asker sample have also been recorded as they may prove useful for comparisons with other species of *Streptis* from elsewhere.

The Exterior of the Valves.

The figured specimen P. M. O. 69597 (pl. 1, figs. 12—15) shows the form of an adult specimen from Asker. The shell is small, of transverse outline with obtusely rounded cardinal angles, the lateral edges curving gently round towards the anterior. The profile is dorsibiconvex

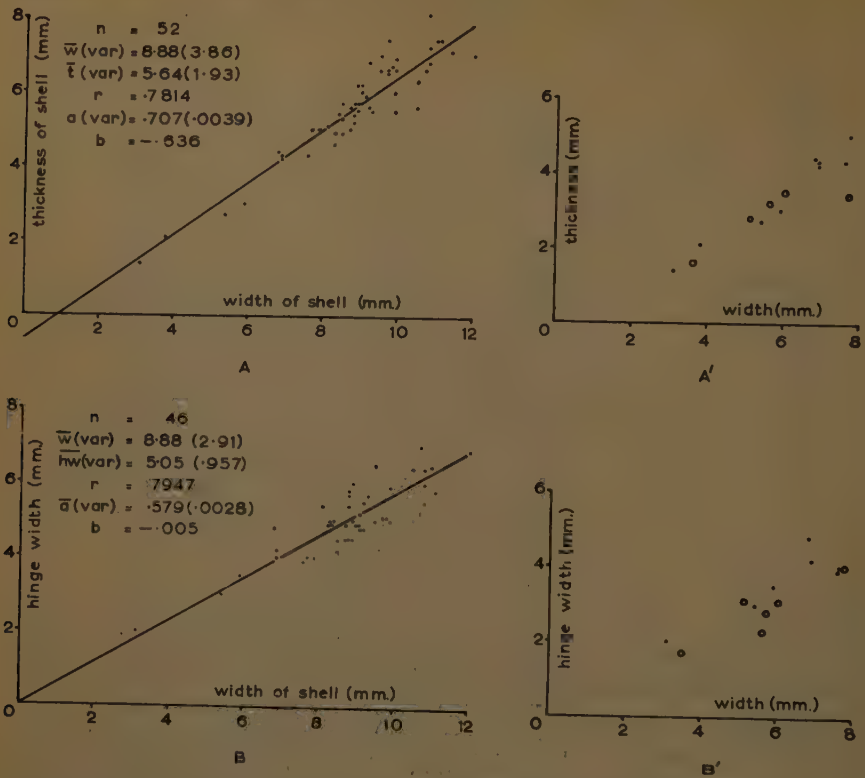

Fig. 4. Scatter diagrams on arithmetical scales of (A) shell thickness plotted against shell width and (B) hinge width plotted against shell width for the Asker sample. A' and B' show the Kildare specimens (circles) plotted with the Asker specimens (dots) of the same size range.

(Schuchert & Cooper, 1932, p. 19) with a well defined fold on the dorsal valve and corresponding sulcus on the ventral. The interarea on the ventral valve is curved, apsacline, with a deltidium that lies flush with the interarea, and which has the narrow elevated fold typical of the Triplesiacea. Contrary to Holtedahl (p. 88) the circular pedicle foramen at the apex of the ventral valve is quite clearly defined (pl. 1, fig. 12).

Outline and convexity. — The outline of the valves may be expressed quantitatively by using the paired variates of width, and, in this sample dorsal, length (Fig. 3). As may seen from the data on the figures, the length: width ratio expressed as a percentage is 72.6 and 77.1

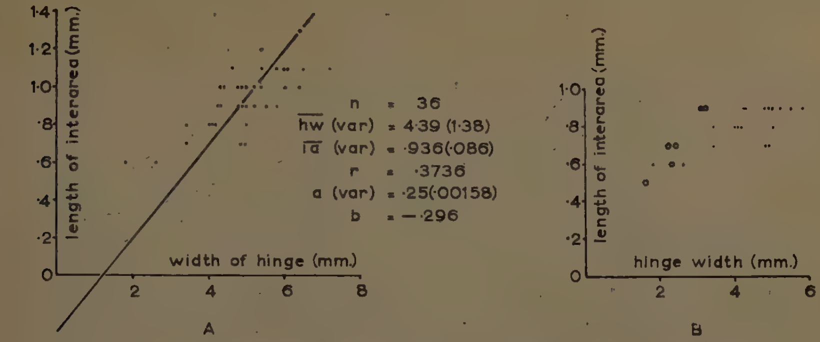

Fig. 5. Scatter diagrams on arithmetical scales plotting the length of the interarea against the hinge width (A) of the Asker sample, (B) of the Kildare specimens (circles) together with the Asker specimens (dots) of the same size range.

in Asker and Kildare forms respectively. It was found that allometric growth took place in the Asker sample. On comparing the α's and also the β's using a pooled value for α ($\bar{\alpha}$) there was shown to be no significant difference between the two samples.

For valve convexity a scatter diagram of thickness against width (Fig. 4A) for the Asker specimens shows the mean thickness to be 63.5 % of the width. Allometric growth did not occur. For 5 Kildare shells the mean thickness to width was 51.8 % (variance 56) and for the 9 Asker shells of a corresponding size range 56.8 % (variance 51.2) (Fig. 4A'). The difference when tested is not significant.

A scatter diagram for hinge width: width of shell with the data for the Asker sample is shown in Fig. 4B. Fig. 4B' shows the Kildare specimens plotted with those from Asker of the same size range. The mean hinge width to valve width for 6 Kildare specimens is 50.3 % (variance 58.6) and for 7 Asker specimens 59.16% (variance 47.7). On testing, the difference between the two samples is not significant ($.1 > P > .05$).

Fig. 5A shows a scatter diagram with data for the length of the interarea plotted against hinge width showing the mean lengths to be 21.3 % of the hinge width for this sample from Asker. A comparison of 6 Irish specimens with 18 Norwegian specimens whose interarea lengths are over the same range shows the proportion to be 29.2 % (variance 10.0) and 19.4% (variance 21.6) respectively, which on testing shows a significant difference between the two samples.

The plication. — The nature of the plication shows considerable variation in the Asker sample (pl. 1, figs. 1—4). The different styles and the relative abundance of those styles in adult forms is indicated on a pictograph (Fig. 6).

Ulrich & Cooper (1936, p. 344) state the species *S. monilifera altosinuata* to be perfectly symmetrical. This is not strictly correct as 12 specimens from the sample (22.2 %) are asymmetrical, although obviously the symmetrical forms do predominate, which is not a normal feature of the genus. It was only possible to examine 5 specimens from Kildare whose length was over 5 mms., which were distributed as follows: g1, b'(1), h1, i1 (1), the numbers in brackets being asymmetrical ones, as on the pictograph. Although only a small sample it seems possible that asymmetry is a more important factor in the Kildare form, and it will also be noticed that 2 of the 5 have plications of the type found in the smaller forms from Asker, i.e. with a dorsal length of under 5 mm. This 5 mm. length dividing the younger forms from the adults is, of course, merely an arbitrary division of convenience: it is not intended to be of biological significance, but it is interesting to note that the low plications restricted to "juvenile"-sized specimens from Asker are present in "adult"-sized specimens in Kildare, suggesting that higher plication of the Asker form is not simply due to the larger size of the shells, but may be a specific character of that form.

The rectimarginate form 'a' (Fig. 6) is restricted to very small shells about 1 mm. or less in size. This is determined from the origin of the plication discussed later (p. 269), not from examination of any specimen of that size. When the plication forms on the dorsal valve, it may develop along one of two principal lines.

The first is from 'b' to 'c', reaching its logical conclusion in 'd'. This line is characterised by plications with a rounded top or crest and sides which diverge in the ventral direction (pl. 1, fig. 4). From 'c', which resembles 'd' but is not so high, the variations 'g' and 'e' are believed to have been developed. Form 'g' is completely asymmetrical (pl. 1, fig. 1) with a rounded shape as in 'c', 'e' is a more narrowly pointed form, which develops into 'f' (pl. 1, fig. 3), having a more angular crest but still possessing the characters of this line, i.e. a rounded crest and divergent sides. Style 'd' is the dominant member of this line forming 22 % of the complete sample.

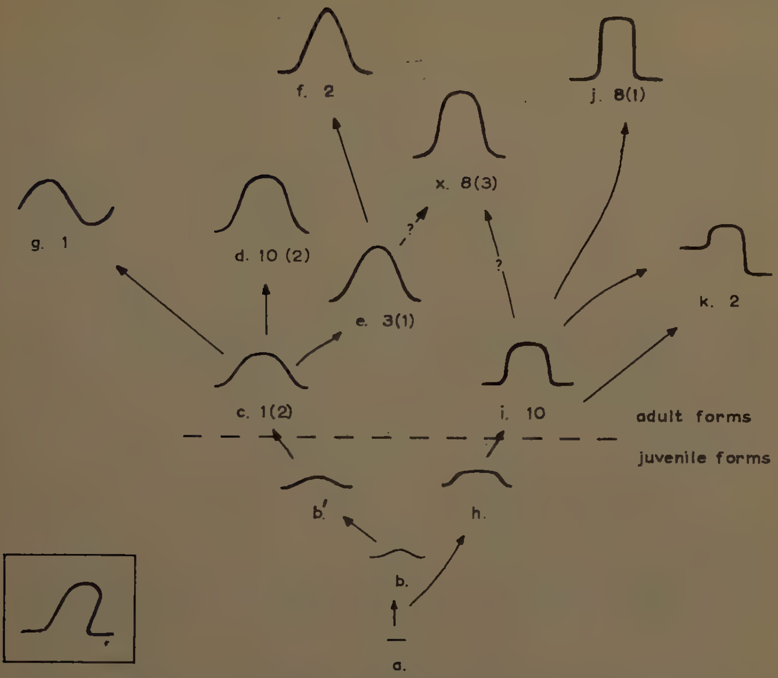

Fig. 6. Pictograph showing the envisaged development of the various styles of anterior commisure of the Asker species. A sample of 54 adult specimens is distributed as shown, the figure in brackets showing the number of specimens which are of that particular form but whose plication is obliquely directed as shown in the inset figure. The juvenile forms are here considered as those specimens whose dorsal length is less than 5 mm.

The other principal line of development is 'h' through 'i' to 'j'. with its asymmetrical offshoot 'k'. This style of fold is characterised by a flattish crest and almost vertical sides (pl. 1, fig. 2). The number ascribed to this line in the sample is about the same as in the line leading to 'd' and its related styles, being 21 and 22 respectively. The remaining 11 specimens display gently diverging almost parallel sides and flattened yet somewhat rounded crests (style x), a profile intermediate in disposition between those characteristic of the two main lines. This style could have developed from 'i' on one hand or from 'e' or 'd' on the other, or alternatively some may have developed from each line.

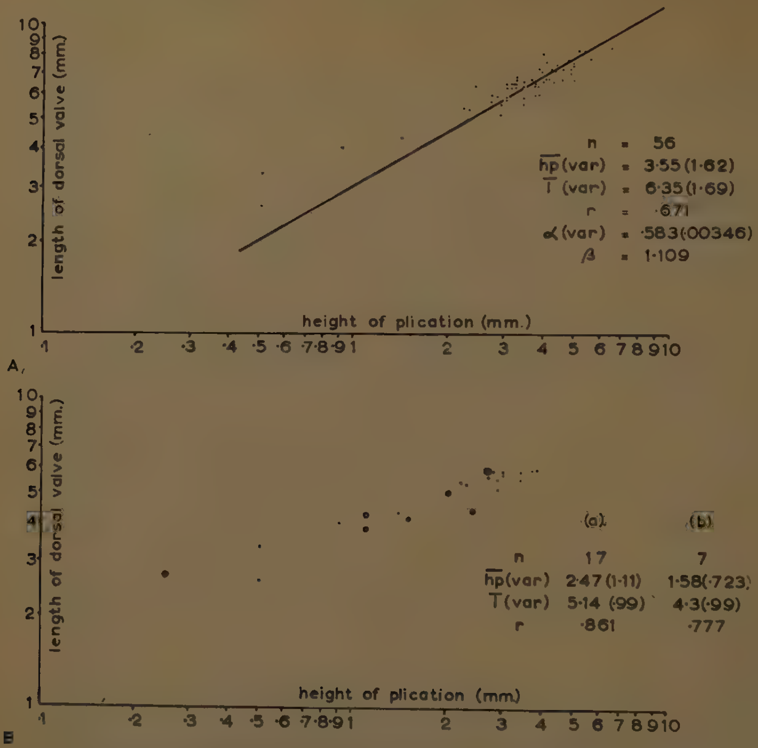

Fig. 7. Scatter diagrams on log scales of dorsal length against height of plication (A) for the Asker sample with reduced major axis shown, (B) for the Kildare specimens (circles) with the Asker specimens (dots) of the same size range.

The scatter diagram obtained by plotting the length of the dorsal valve against height of the plication is shown (fig. 7A) with the data. The growth for this is allometric. An average shape comparison (KERMACK, p. 408) was carried out on the Kildare forms and the Asker ones of the same size range (fig. 7B), but the difference between the two samples was not significant ($.1 > P > .05$).

The width of the plication was also plotted against the dorsal length (fig. 8A). Allometric growth again occurred, but a comparison of both the a values and the β values revealed no significant difference. Allometric effects were also found in an investigation of the height against the length of the plication (fig. 8B). Here too, no significant difference was found between the two samples.

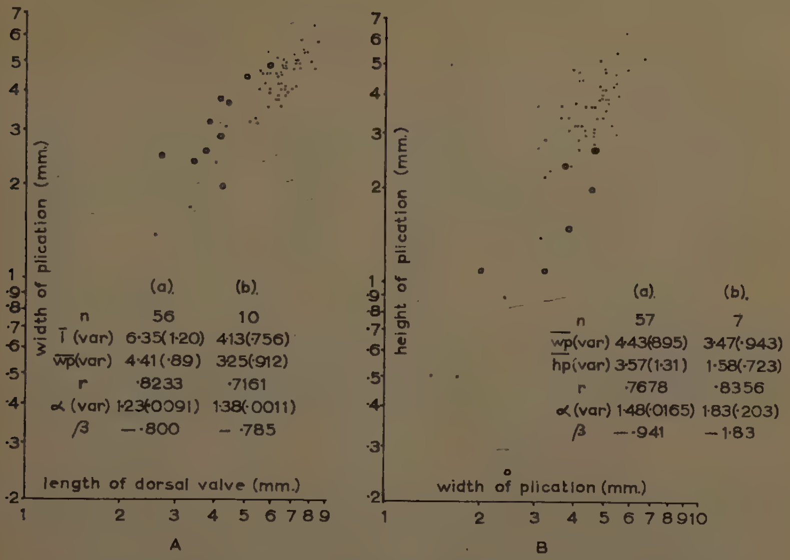

Fig. 8. Scatter diagrams on log scales of shells from Asker (dots) and Kildare (circles), (A) of the width of the plication against the length of the dorsal valve, (B) of the height against the width of the plication. In the tables (a) refers to the Asker form and (b) to the Kildare form.

The position of origin of the plication does show a statistically significant difference between the two stocks. For a sample of 40 Asker valves the mean distance of origin from the umbo of the plication was 1.16 mm. (variance .043) and for 24 Kildare valves it was 2.0 mm. (variance .065), showing a much later development of this feature in the Kildare shells.

The nature of the ornament. — Holtedahl (p. 88) described the ornament as being that typical of the genus *Streptis*, "a number of delicately concentrically arranged ridges, each marked as can be seen in good preservation by a row of small tubercles" the detailed form of which Holtedahl was not able to study in any specimen. Ulrich & Cooper (p. 344) have since stated the ornament of the genus *Streptis* to be formed of strong lamellae, on which are superimposed fine radial costellae. The reinvestigation of the Asker species has shown this to be borne out in the case of the Norwegian forms too.

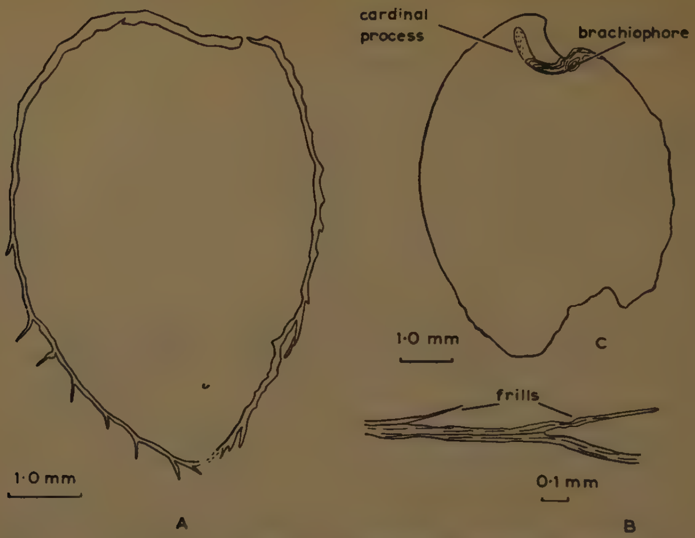

Fig. 9. Longitudinal sections through *Streptis altosinuata* HOLTEDAHL. A. A cellulose peel of a slightly oblique section showing the disposition of the frills relative to the shell surface. B. A thin section of the shell at larger magnification showing the frill — shell surface relationships as indicated by the growth lines. C. Section showing the disposition of the cardinalia drawn from a series of peels.

The lamellose skirts, or frills, are very delicate and are almost invariably broken off when the shells are removed from matrix, although examples are to be found with frills or parts of frills still intact (pl. 1, figs. 8,22). Exceptionally a pathological specimen occurs in which the frill is developed in the plane of the shell (pl. 1, fig. 5) instead of extending away from the surface of the valve.

A closer look at the structure of the frills was obtained by sectioning specimens whilst still in their matrix, and producing either a cellulose peel or a thin section. Fig. 9 A shows a specimen with several frills preserved and indicates their relative size and attitude to the shell. Fig. 9B shows individual frills, the growth lines of which show that after deposition of a frill the shell secreting outer epithelium was retracted from the tip of the frill by over twice the length of the projecting frill before it advanced again to continue building up the shell. The result of the thin delicate nature of the frills is that, as stated

	Asker	Kildare
n	53	31
m (mm.)	·387	·52
Var. m	·007	·022

A

	4 — 6 costae	7 — 9 costae
Frequency of Asker form	7	23
Frequency of Kildare form	13	2

B

Table 1. A. Table showing a comparison of the Asker and Kildare samples on the wavelength of the frill bases (m).

B. 2 × 2 Table comparing the number of radial costae on the median 2 mms. of the frill base 3 mms. from the dorsal umbo (fig. 1C, i) for the two samples.

above, they are easily broken, so that by far the majority of the shells (e.g. pl. 1, fig. 11) show merely a series of concentric frill bases, ridged by radial ornament. In between the frill bases the surface is ornamented by fine concentric growth-lines, usually from about 3 to 5 being counted between succeeding frill bases. No statistical assessment of these growth lines was attempted.

The frill bases themselves, however, proved excellent for statistical purpose. They are generally close together posteriorly, becoming wider apart by midvalve, then closer set anteriorly. This would seem to correspond to the youthful stage, the adult stage and then to old age, when less shell deposition takes place between each successive frill. It is, however, appreciated that the smaller quantity of shell deposited between frills in the late stages may be due to the greater convexity of the valves, causing the growth of the anterior margins to be directed more in a ventral or dorsal direction rather than in an anterior direction, in which case development of one valve would be restricted by the opposing valve. It is interesting to note that this closing together of the frill bases is not nearly so apparent in the Kildare forms. Because of this variation over the surface of individual specimens it is necessary to take all measurements at one particular point on the shell, and in this case they were taken at a distance of 3 mm. anterior to the dorsal umbo (p. 261).

The mean wavelength of the frill bases for the two samples may be seen in Table 1A. The larger wavelength of the Kildare form is signifi-

length of dorsal valve (mm.)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
7·5-7·99	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1	1	1	·	1	·	·
7·0-7·49	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1	1	1	1	·	·
6·5-6·99	·	·	·	·	·	·	·	·	·	·	·	·	1	·	3	1	·	·	2	1	[illegible]
6·0-6·49	·	·	·	·	·	·	·	·	·	·	·	·	3	1	7	1	4	2	2	1	·
5·5-5·99	·	·	·	·	·	·	·	1	·	1	·	2	·	2	2	3	·	·	·	·	·
5·0-5·49	·	·	·	·	·	·	·	·	·	1	2	4	2	2	2	·	·	·	·	·	·
4·5-4·99	·	·	·	·	1	·	·	·	5	2	5	·	4	2	1	·	·	·	·	·	·
4·0-4·49	·	·	·	·	·	·	2	6	1	4	4	2	·	·	·	·	·	·	·	·	·
3·5-3·99	·	·	·	·	·	2	4	4	9	3	1	·	·	·	·	·	·	·	·	·	·
3·0-3·49	·	·	·	1	6	5	8	4	3	·	·	·	·	·	·	·	·	·	·	·	·
2·5-2·99	·	·	1	6	8	5	·	1	·	·	·	·	·	·	·	·	·	·	·	·	·
2·0-2·49	·	2	3	3	4	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
1·5-1·99	1	3	4	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
1·0-1·49	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
·5-·99	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
0-·49	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·

number of frill bases →

Table 2. Table of length of dorsal valve × number of frill bases for the Asker sample.

cantly different, which is apparent when, for example, pl. 1, fig. 7 is compared with the Asker forms. The numbers of radial costae on a frill along the median 2 mms. of frill length are also compared for the two samples in a 2 × 2 contingency table (Table 1B). The two are shown to be significantly different, the Asker form having more, finer costellae per unit length than the Kildare specimens.

Tables 2 and 3 show the length of the dorsal valves, x the number

length of dorsal valve (mm.)	1	2	3	4	5	6	7	8	9	10	11	12
6·0 6·49	·	·	·	·	·	·	·	·	1	·	·	·
5·5 5·99	·	·	·	·	·	·	1	·	·	2	·	1
5·0 5·49	·	·	·	·	·	·	·	1	1	·	·	·
4·5 4·99	·	·	·	·	·	1	1	1	1	·	·	·
4·0 4·49	·	·	·	·	1	3	1	4	2	·	·	·
3·5 3·99	·	·	·	5	1	2	4	1	·	·	·	·
3·0 3·49	·	·	1	4	5	2	·	·	·	·	·	·
2·5 2·99	1	2	7	4	2	·	·	·	·	·	·	·
2·0 2·49	5	5	4	·	·	·	·	·	·	·	·	·
1·5 1·99	7	·	1	·	·	·	·	·	·	·	·	·
1·0 1·49	·	·	·	·	·	·	·	·	·	·	·	·
5 ·99	·	·	·	·	·	·	·	·	·	·	·	·
0 ·49	·	·	·	·	·	·	·	·	·	·	·	·

number of frill bases →

Table 3. Table of length of dorsal valve × number of frill bases for the Kildare sample.

	1 — 4 frill bases	5 — 8 frill bases
Frequency of Asker form	15	19
Frequency of Kildare form	28	2

A

	7 — 11 frill bases	12 — 16 frill bases
Frequency of Asker form	5	19
Frequency of Kildare form	5	1

B

Table 4. 2 × 2 tables comparing the numbers of frill bases of the two samples, A for young specimens 2—3 mm in length, B for adult specimens 5—6 mms in length (compiled from Tables 2 and 3).

of frill bases for the Asker and Kildare samples respectively. 2 × 2 tables are shown for both young specimens (between 2 and 3 mm. in length) and for adult specimens (between 5 and 6 mm. in length) in tables 4A and B respectively. The difference in both cases shows the significantly larger number of frill bases on the Asker forms.

The Interior of the Valves.

Several specimens of the Asker material revealed the pattern of the muscle scars in both valves, when the shell was removed from the umbonal regions (pl. 1, fig. 6, 10, 11). The muscle scars have not previously been recorded for the genus although Reed (1909, p. 152) has described the internal characters in his species *Streptis affinis* from the Llandeilo (?) beds of Tourmakeady, Co. Mayo, Ireland. This species may be referred to the Syntrophiacea and is quite separate from the genus *Streptis.*

The disposition of the muscles (Fig. 10) conforms closely to the

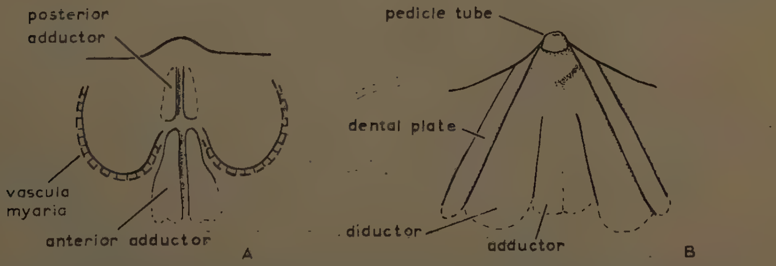

Fig. 10. The muscle scar arrangement in *Streptis altosinuata* Holtedahl in (A) dorsal and (B) ventral valves, × 15.

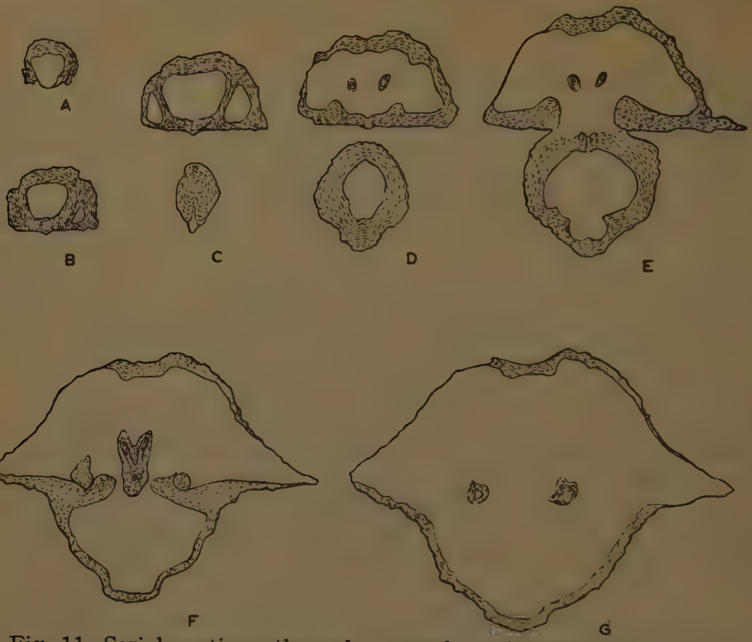

Fig. 11. Serial sections through a partly exfoliated specimen of *Streptis altosinuata* HOLTEDAHL taken at .2mm intervals, A itself being .2 mms from the tip of the ventral valve, × 15.

typical triplesiid pattern known from other genera. The ventral interior shows a pair of narrow diductor scars bounded on the outside by a pair of divergent dental plates, and on the inside by a smaller pair of adductor scars. In the dorsal valve the familiar quadrate pattern is seen with a narrow posterior pair of deeply impressed adductor scars, separated by a transverse ridge from the anterior pair. The latter are larger, broadening out anteriorly. Both pairs of scars are divided by a low but well-defined ridge along their length.

The only evidence of pallial sinus patterns in this species was the impressions of a pair of arcuate vascular myaria appearing between the posterior and anterior muscle scars and curving round posteriorly, presumably enclosing the gonocoeles. This again is typical of the family. The ventral interior also possesses a small pedicle tube (pl. 1, fig. 11, and text. fig. 10B) which evidently sheaths the pedicle between the foramen and the seat of attachment of that organ on the floor of the valve posterior to the adductor scars. This feature is stated by HAVLI-

CEK (1950, p. 87) to characterise his genus *Bicuspina,* but it is also known from other forms such as *Cliftonia lamellosa* (WILLIAMS, 1951, p. 105).

Serial sections through a specimen from Asker (Fig. 11) show in the ventral valve the dental plates (B, C) and the continuation of the teeth in D, E and F; the deltidium with its characteristic median fold, and in B is a patch of non-fibrous calcite filling the pedicle tube.

In the dorsal valve E shows the ventral indentation of the growth lines produced by the median fold of the deltidium, F the sockets and divergent brachiophores, the latter also being seen in G. The forked cardinal process, a very conservative feature in the Triplesiacea, is well seen in F where on the dorsal side it is cut across in its young stages, showing the process to be forked even in the very juvenile forms. The distal ends of the process are directed posteriorly and are shown in the transverse sections as points extending towards the ventral umbo (E, D). The appearance of the process in longitudinal section is shown in Fig. 9C.

Conclusions.

The strong resemblance of *Streptis monilifera* M'COY to the Norway form was observed by HOLTEDAHL (p. 88), who said that the two could be separated by some different characters, none of which was of great systematic importance, citing the stronger plication of the Norway form and also the larger number of frill bases, and stating the young Norwegian forms to be very similar to the British specimens, due to the smaller number of frill bases and to the lower plication on the young shells.

As has been shown, a comparison of the height and width of the plication to each other and to the length of the valve in each case (p. 268) shows that there is no significant difference, the apparent higher plication in the Norwegian forms being due to the greater size of the shells. Thus the only valid difference indicated by HOLTEDAHL is that of the number of frill bases, where he states that 10 frill bases are usual in young Asker forms, compared with 8 — 9 in the British. On these grounds it would certainly not be prudent to separate them into two species.

A statistical approach, however, enables the differences to be seen with much greater clarity. The differences are summarised as follows.

1. The ornament — the Asker form has more, closer spaced radial costellae situated on frill bases whose wavelength is smaller than the Kildare form, and further it does possess more frill bases.
2. The plication — differs in that it develops at a significantly earlier stage in the Asker form.
3. The shape of the interareas is significantly different, that of the Norwegian form being wider relative to length than the Kildare form.

The presence of significant differences in three unrelated features of the shell justifies the separation of the Asker form into a separate species *Streptis altosinuata* HOLTEDAHL.

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Manuscript received May 13, 1960.
Printed November 1960.

PLATE 1

PLATE 1.

The photographs are not retouched, but the specimens were coated with ammonium chloride before photographing. Abbreviations of repositories: P.M.O. = Palaeontological Museum of the University of Oslo; G.S.M. = Geological Survey and Museum, London; A = Author's collection.

Streptis altosinuata HOLTEDAHL, 1916.

All specimens of this species figured are from the Lower Llandovery (6a—b) of Konglungen, Asker, Norway. Coll:. Johan Kiær, 1906.

Fig. 1—4. Specimens showing various forms of the anterior commissure: Respectively P.M.O. 69587, × 3.1, asymmetrical; P.M.O. 69588, × 3.2, with a deep U-shaped sulcus; P.M.O. 69589, × 3.0, sulcus deep, V-shaped; P.M.O. 69590, × 3.2, sulcus somewhat shallower and more rounded.

Fig. 5. Ventral view of a pathological specimen in which one frill has developed in the plane of the shell. P.M.O. 69591, × 2.6.

Fig. 6. Postero-dorsal view of a partly exfoliated shell to show the dorsal musculature. P.M.O. 69592, × 5.3.

Fig. 8. Dorsal view of a shell, showing a portion of one frill protruding away from the shell surface. P.M.O. 69593, × 3.1.

Fig. 9. Latex cast of specimen P.M.O. 69594, showing the frill. P. M. O. 69594, × 4.3.

Fig. 10. Postero-dorsal view of an incomplete specimen exfoliated posteriorly to show adductor scars and part of the vascular myaria. P.M.O. 69595, × 3.2.

Fig. 11. Ventral view of specimen exfoliated posteriorly to reveal the muscle scars of the ventral valve. P.M.O. 69596, × 5.3.

Fig. 12—15. Posterior, dorsal, ventral and lateral views of specimen P.M.O. 69597, × 3.1.

Fig. 19, 23. Dorsal and ventral views of young specimen. P.M.O. 69598, × 5.8 and × 5.5 respectively.

Fig. 22. Dorsal view of specimen showing fragments of four separate frills preserved. P.M.O. 69599, × 5.5.

Streptis monilifera (M'COY, 1846).

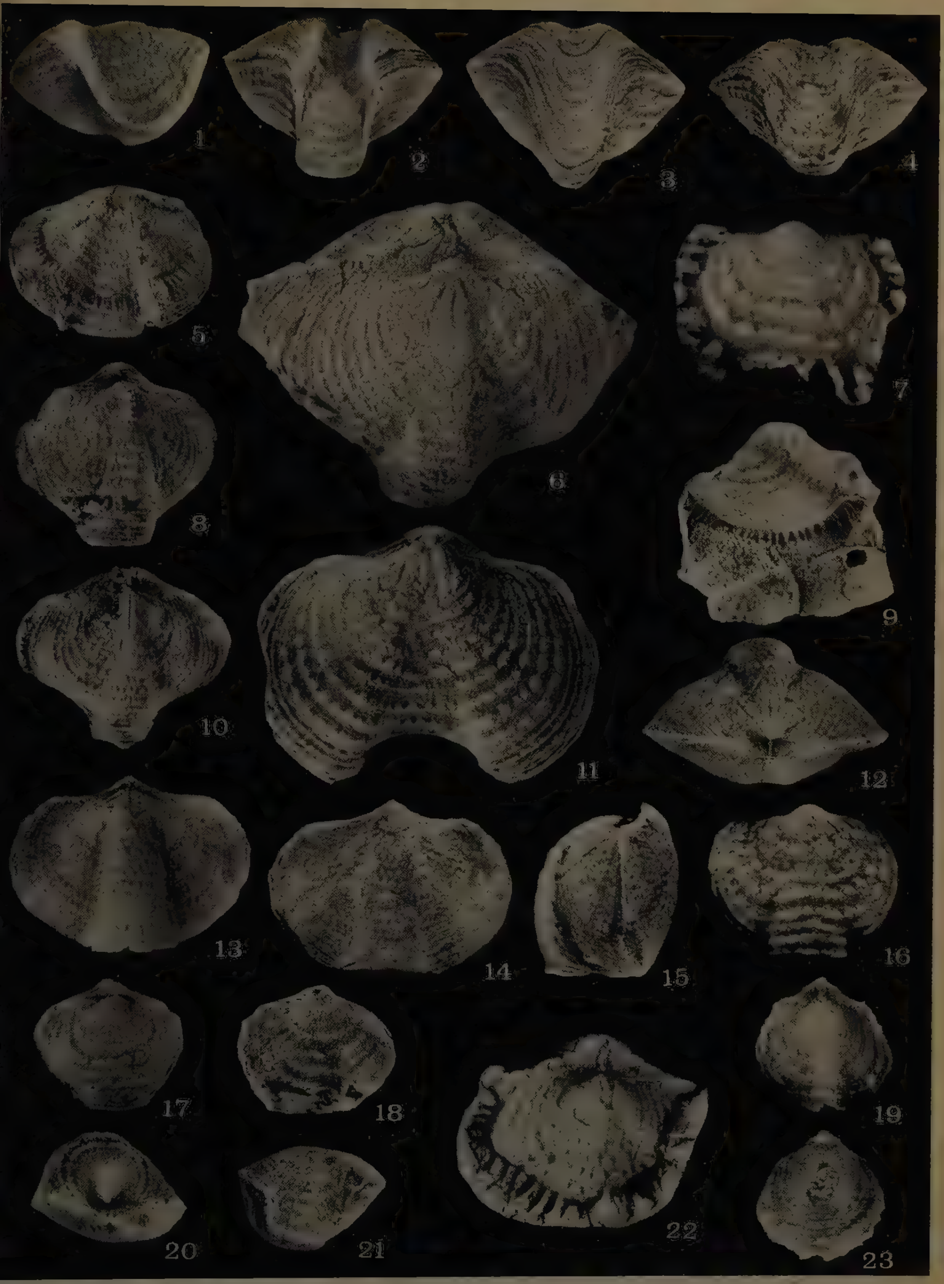
Specimens from the high Ashgillian Chair of Kildare Limestone, Kildare, Ireland.

Fig. 7. Dorsal valve with frill preserved. A. × 5.5.

Fig. 16. Dorsal valve. G.S.M. 11199, × 4.7.

Fig. 17—21. Dorsal, ventral, posterior and anterior views of a complete specimen. A. × 3.3.

PLATE 1.



CONTRIBUTIONS TO THE MINERALOGY OF NORWAY

No. 8. Davidite from Tuftan, Iveland

BY

HENRICH NEUMANN and THOR L. SVERDRUP[1]

In 1956 a quantity of gadolinite from the Tuftan pegmatite dyke was sold to an American firm dealing in rare element raw materials. To his surprise the Norwegian exporter received a complaint that the gadolinite was of inferior quality and could not be accepted. A sample of the exported material was sent to this Museum for examination and the bulk of it was found to be a black metamict amorphous mineral, in appearance strikingly like gadolinite. However, by its X-ray powder pattern when heated, and by semiquantitative optical spectrograms the material was identified as davidite. A sample of the same material had found its way into the collections of dr. H. F. Harwood in Wales who sent it to the Atomic Energy Division of the Geological Survey of Great Britain where dr. J. E. T. Horne coincident with us identified it as davidite, and kindly sent us a copy of his report (Mineralogical report No. 621, dated 20th September, 1957).

Mode of occurrence.

The Tuftan pegmatite dyke is situated in the northern part of the pegmatite district of Iveland, north of Kristiansand in southern Norway. (2). It is apparently nearly vertical, strikes about NW, and is more than one hundred meters long. The Tuftan dyke is probably richer in rare minerals than any other granite pegmatite in this country and is one of the very few dykes in Norway worked for rare minerals (thortveitite, gadolinite and euxenite) yielding some feldspar and quartz as by—products. The following mineral species have been found: microcline, plagioclase, quartz, biotite, muscovite, garnet, allanite, zircon, beryl, gadolinite, thortveitite, euxenite, blomstrandine, davidite, magnetite, ilmenite, rutile, xenotime, pyrite, and molybdenite.

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[1] Now at Norges Geologiske Undersøkelse.

All together about 200 kilograms of davidite have been found in the Tuftan dyke. The davidite occurs as elongated masses with rough semi-linear outlines attaining a length of 20 cms. or even more.

The davidite is always to a greater or lesser degree transected by tiny veinlets or small irregular elongated masses of an intergrowth of ilmenite and rutile with smaller amounts of feldspar, quartz, muscovite, and biotite as illustrated by fig. 2. The structure would seem to indicate that the ilmenite-rutile intergrowth is younger than the davidite, having replaced the latter along cracks which possibly to some extent follow cleavage directions in the originally crystalline mineral. However, as seen in fig. 2 the ilmenite-rutile intergrowth is full of cracks which only very exceptionally continue into the davidite, and this might be interpreted as an indication that davidite has replaced an older mass of ilmenite and rutile with pre-existing cracks. If so, one would expect the replacement to take place preferentially along these cracks, which is not the case, however; the cracks characteristically stop against a smooth contact line between the ilmenite-rutile intergrowths and the davidite. The formation of these cracks is probably

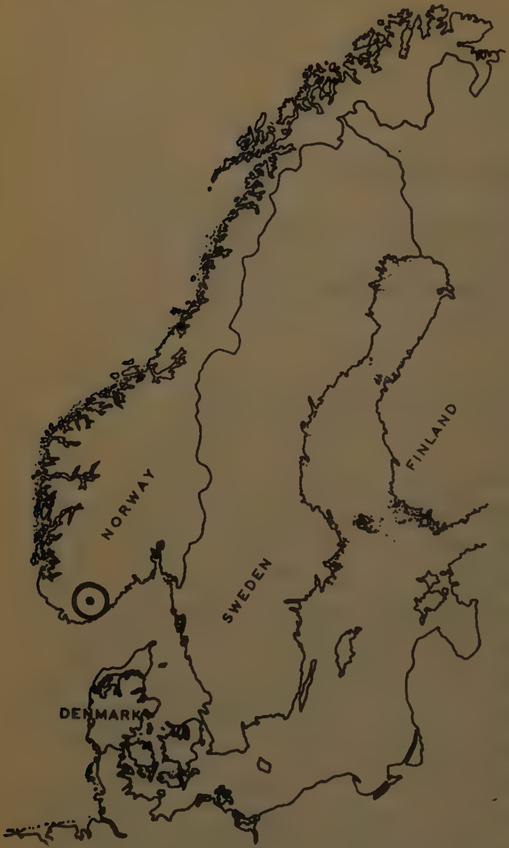

Fig. 1. Key map. The dot with a ring around it indicates the location of Tuftan, Iveland.

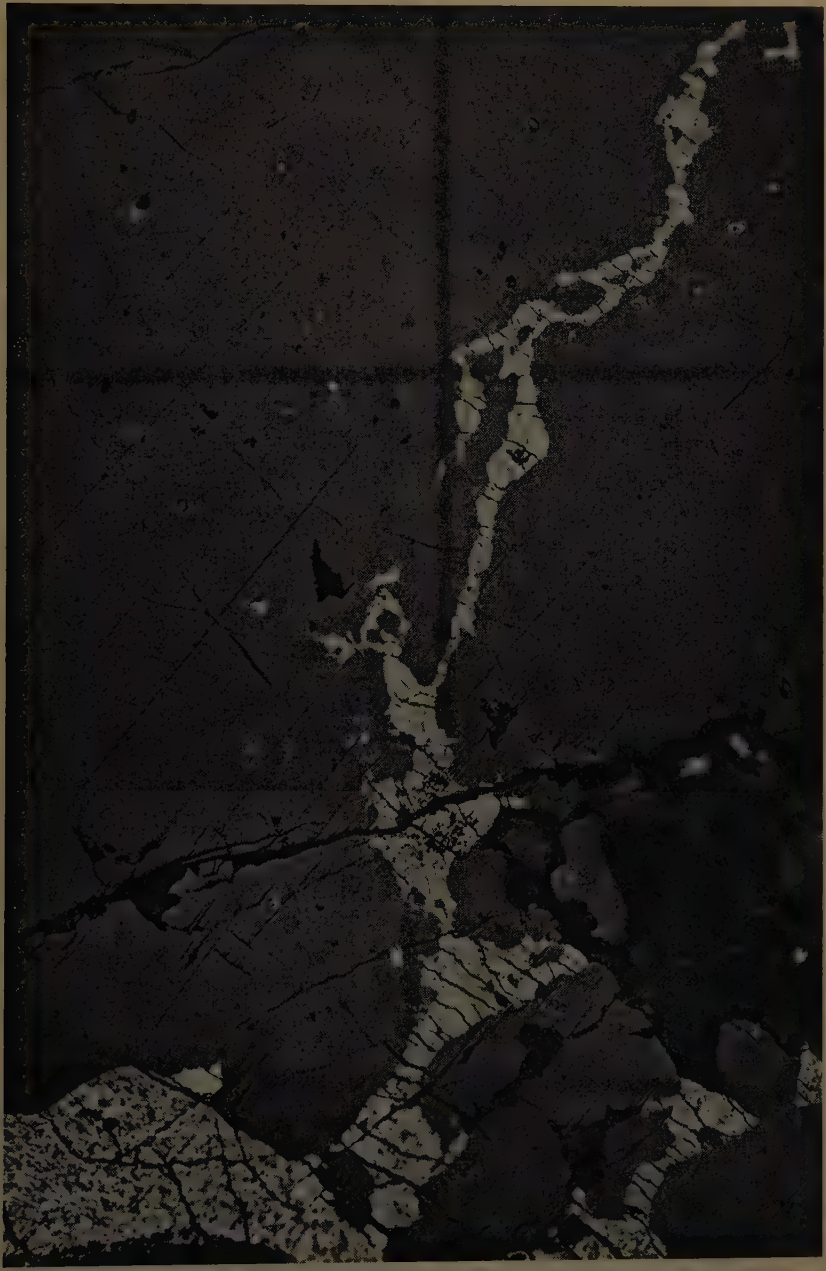

Fig. 2. Polished section of davidite. Dark gray: davidite. Light gray: intergrowth of ilmenite and rutile in veinlets. Very dark gray with internal reflections: silicates. Magnification 70x.

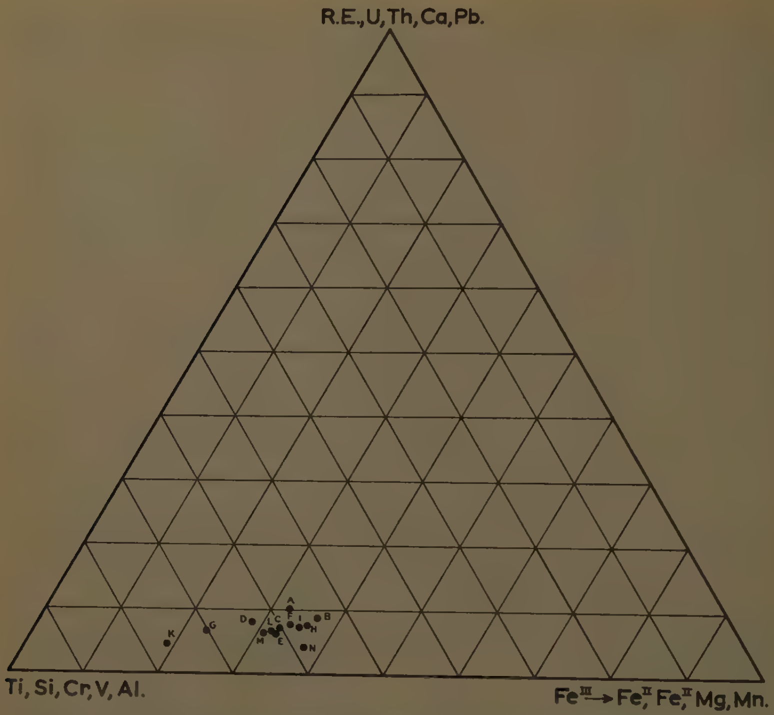

Fig. 3. Chemical composition of davidites plotted on a triangular diagram in atomic percentages. Letters refer to analyses in table 1.

a secondary phenomenon caused by an increased internal pressure during metamictization which cracked the tiny veinlets of ilmenite and rutile without affecting the main massive mass of homogenous davidite. If so these cracks are of no consequence for the interpretation of the age relations between davidite and the ilmenite-rutile veinlets. With proper consideration of the inherent difficulties in deciding relative ages on the basis of structures of this kind it is concluded that in all probability the older davidite was before metamictization replaced by the younger veinlets of ilmenite and rutile.

Physical properties.

The davidite from Tuftan in unweathered splinters is completely black with a shining vitreous luster. It has a subconchoidal fracture with no signs of cleavage directions. The streak or powder colour is black or very dark gray. Oxidized surfaces often have a brown or reddish colour.

Only five small incomplete crystals of davidite, 2—5 cm. across have been found, and they are not sufficiently well developed to be measured even with a contact goniometer. The crystals may be hexagonal like those described by Bannister and Horne (1) from Mozambique.

The hardness is 6, and the specific gravity of the analyzed material is 4.29.

The mineral is opaque exept at the very edges of extremely thin splinters where it is translucent with a clove-brown colour. It takes a good polish and is gray and isotropic in polished sections. Apart from the tiny veinlets of ilmenite and rutile mentioned above it is homogenous even at the highest magnifications.

Chemical composition.

Splinters of davidite which appeared free from impurities when observed with a binocular lens were crushed and then cleaned further with a Frantz isodynamic separator with scores of runs with varying inclinations and field strengths. Even so the material analyzed was not as perfectly free from inclusions as could be desired, but the amount of impurities was less than 3 %.

The analysis, made by B. Bruun, is quoted as A in table 1. together with published analyses of davidite from other localities for comparison.

The atoms constituting the original davidite structure which later collapsed are obviously in addition to oxygen the major elements of the analyses: titanium, iron, rare earths, and uranium. The other elements found in subordinate amounts either substitute for the major elements or originate from impurities. Lead is supposedly a decay product of uranium and was not present in davidite when it first crystallized.

The analyses of table 1. are arranged in order of decreasing rare earth content. It is easily seen that the uranium content in a general way increases as the content of rare earths decreases[2] and there can hardly be any doubt that uranium substitutes for the rare earths in

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[2] An exception is analysis K, see comment p. 284. It is very surprising that no rare earth content is reported in analyses M and N. The presence of La is, however, shown by spectrographic analyses (7, p. 154). A reexamination of these davidites would certainly be of interest.

Table 1. *Analyses of Davidite (Weight per cent).*

	A[1]	B	C	D	E	F	G	H	I	K	L	M	N
SiO_2	0.34	0.1	0.2	1.4	1.3		4.6	0.2	0.9	4.4	0.06	3.29	6.02
TiO_2	52.1	49.0	50.7	53.0	49.8	54.3	49.8	45.3	47.0	53.6	54.5	54.03	46.72
$R.E._2O_3$	17.3[2]	12.8	11.6	11.3	8.8	8.3	8.2	7.6	7.0	6.4	5.6		
ThO_2											0.07		
Al_2O_3		3.1	1.7		1.1		4.3	2.0	0.7	4.2		3.53	1.05
ZrO_2											0.4		
Cr_2O_3			0.7	0.4	1.1	4.6	0.7	1.3	0.6	1.5	0.17	0.04	
V_2O_5			1.2	1.8	2.7		0.4	0.6	1.5	6.1	1.4	2.26[4]	2.88[4]
U_3O_8	1.1[3]										9.8	2.17	6.41
UO_2		1.5	2.3	4.3	3.6		5.6	7.7	8.8	2.8			
Fe_2O_3	9.5	6.8	29.8	25.3	29.9	13.0	20.7	32.1	31.6	17.6	10.2	12.43	16.53
FeO	17.1	23.9				16.0					16.5	15.61	18.33
PbO	n. d.	0.1	0.5	0.7	0.7	1.1	1.0	1.5	0.9	0.9	0.72		
MnO	1.0											0.25	0.61
Mn_3O_4		0.3											
MgO												1.20	0.17
CaO		0.7				1.5					0.3	4.50	1.71
Na_2O											0.15		
K_2O													
H_2O	1.63			1.2		1.5			1.2		0.05		
Loss on ignition			0.3		nil		3.6	0.5		0.9			
Insoluble				0.5					nil				
Sum	100.07	98.3	99.0	99.9	99.0	100.9	98.9	98.8	99.8	98.4	99.98	100.43	101.54

Text to table 1.

A. Davidite from pegmatite, Tuftan, Iveland, Norway. Analyst B. Bruun. B. Davidite from pegmatite, Mt. Pleasant, Australia. Analyst J. D. Hayton (9.) C. Davidite from pegmatite, Billeroo, Australia. Analyst D. Bowditch. (9.). D. Davidite from Whip Lode, Radium Hill, Australia. Analyst J. D. Hayton. (9.). E. Davidite from pegmatite, Broken Hill. Australia. Analyst D. Bowditch. (9.). F. Davidite from a hydrothermal lode, Olary, Australia. (Type locality). Analyst W. T. Cooke. Quoted from (1.). G. Davidite from fractured quartzite, Spring Hill, Australia. Analyst D. Bowditch. (9.). H. Davidite from calc-silicate rock, Mt. Isa, Australia. Analyst D. Bowditch. (9.). I. Davidite from David Lode, Radium Hill, Australia. Analyst J. D. Hayton. (9.). K. Davidite from lodes, Mt. Victoria, Australia. Analyst D. Bowditch. (9.). L. Davidite from calc-silicate rock, Mavuzi, Tete, Mosambique, Portuguese East Africa. Analysts Ryan, W., and Maple, P. J. (1.). M.[5] Davidite from a schist? (not found in situ), Six Kangaroos Lease, midway between Mt. Isa and Cloncurry, Australia. Analyst G. T. See. (7.). N.[5] Davidite from a segregation lens of brown calcite in granulite, Dajarra, south of Cloncurry, Australia. Analyst G. T. See. (7.).

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[1] A spectrographic analysis by C. D. Harvey of the Atomic Energy Division of the Geological Survey of Great Britain shows the presence, "but of probably only very minor significance", of the following elements in addition to those reported in the analysis: Nb, Sc, Sn, V, Zr, Ca, and Al. I. Oftedal determined the scandium content of the analyzed material of davidite from Tuftan and found ~ 0.05 % Sc_2O_3.

[2] O. Joensuu made a differential analysis of the ignited precipitate of rare earths by optical spectrographical methods and found: Y_2O_3 23 %, La_2O_3 22 %, CeO_2 32 %, Pr_6O_{11} 2.4 %, Nd_2O_3 2.8 %, $Sm_2O_3 < 0.2$ %, Eu_2O_3 0.4 %, $Gd_2O_3 < 0.1$ %, $Tb_4O_7 < 0.2$ %, Dy_2O_3 1.6 %, Ho_2O_3 0.55 %, Er_2O_3 2.5 %, Tm_2O_3 1.2 %, Yb_2O_3 9.5 %, Lu_2O_3 1.7 %, ThO_2 1.5 %.

[3] U_3O_8 content is determined by Forsvarets Forskningsinstitutt. An independent radiometric assay of a different sample by E. F. Bunt of the Atomic Energy Division of the Geological Survey of Great Britain gave 1.1 % *e* U_3O_8.

[4] Vanadium content determined as, and figures given for V_2O_3.

[5] Lawrence, L. J., et al. (7.) make selfcontradictory statements in the text of their paper pp. 140—142 and under the table with chemical analyses p. 144. Consequently the locality given here for davidite, analysis M, may actually be the locality of davidite analysis N, and vice versa.

the davidite structure, as it usually does in rare earth minerals. All the davidites with low rare earth contents are, however, somewhat deficient in uranium, which is in all probability a seondary phenomenon due to the fact that uranium is easily oxidized to its sixvalent state and then leached by circulating waters.

The role of H_2O in metamict amorphous minerals is in many cases a controversial matter as it may be either an essential constituent of the original crystalline mineral or it may be adsorbed during or after the metamictization. In the case of davidite the water content is always fairly low. It is given as only 0.05 % in analysis L which appears to be very reliable in every respect, also as fas as purity of the analyzed material is concerned which has been a major difficulty in davidite investigations. It seems reasonable, therefore, to conclude that the original, non-metamict davidite was a water-free mineral.

The actual state of oxidation of iron in davidite is hard to ascertain. In seven of the thirteen analyses quoted in table 1. ferrous iron was not determined and in the remaining six the relative amounts of ferrous and ferric iron vary within wide limits. In analyses A and L the atomic proportions $Fe^{2+} : Fe^{3+}$ is close to 2 : 1 which may be incidental or may not. In analysis B the Fe_2O_3 content is so low that it is very tempting to assume that the trivalent iron now found in davidites is formed by later oxidation, and that the iron contained in the original crystalline davidites was divalent, perhaps with some trivalent iron substituting for titanium.

There are several reasons why it would seem a difficult and uncertain task to try to calculate a gross formula for davidite: The analyzed material appears from published descriptions in most cases to have been badly contaminated by other minerals, first of all rutile, ilmenite, magnetite, and hematite. Differential analyses of the rare earths are lacking except for the davidite from Tuftan (see table 1., analysis A, note 2)[3]. Also davidites have apparently in most or all cases been oxidized after their formation, and uranium may have been removed to a greater of lesser extent by selective leaching.

[3] While this paper was in print A. Kvalheim of Statens Råstofflaboratorium analyzed the ignited precipitate of rare earths by X-ray spectrographical methods and found: Y_2O_3 20.6 %, La_2O_3 17.3 %, CeO_2 39.2 %, Pr_2O_3 1.8 %, Nd_2O_3 3.8 %, Sm_2O_3 0.2 %, Eu_2O_3 nil., Gd_2O_3 trace, Tb_2O_3 trace, Dy_2O_3 1.5 %, Ho_2O_3 0.7 %, Er_2O_3 2.3 %, Tm_2O_3 1.0 %, Yb_2O_3 9.9 %, Lu_2O_3 1.7 %, ThO_2 1.4 %.

It is quite surprising, therefore, that a calculation of the analyses seems to indicate a fairly simple gross formula if the following reasonable assumptions are made:

1) In lack of better data the modecular proportions of the rare earths are calculated on the assumption that all davidites have the same distribution of rare earths as has the davidite from Tuftan.

2) Iron was originally present as Fe^{2+} and was later to a greater or lesser extent oxidized to Fe^{3+}.

3) Uranium originally present in its fourvalent state was later to some extent oxidized to sixvalent uranium which was partly or wholly removed by leaching. Davidite would consequently tend to be deficient in uranium, especially those davidites which are low in rare earths and high in uranium.

Atomic percentages were calculated and the cations grouped together as large cations (R. $E.^{3+}$, U^{4+}, Pb (originally U^{4+}), Th^{4+}, Ca^{2+}), middlesized cations (Fe^{2+}, $Fe^{3+} \rightarrow Fe^{2+}$, Mg^{2+}, Mn^{2+}) and small cations (Ti^{4+}, Si^{4+}, Al^{3+}, Cr^{3+}, V^{5+}). In fig. 3 the results are plotted on a triangular diagram and in spite of the impurity of many of the analyzed samples the plots crowd together within a fairly small area. Exceptions are analyses G and K of the davidite from Spring Hill and Mt. Victoria and these are both reported (9) to contain numerous inclusions of rutile (and other minerals). If these analyses are corrected for a content of 10—15 % of rutile they will also be within the same small area as the others. If the majority of the plots are slightly «lifted» in the diagram to correct for the supposed deficiency in uranium they will all be quite close to a composition corresponding to a proportion of large ions: middlesized ions: small ions = 1 : 3 : 6, or for the pure rare earths end member $Y_2\ Fe^{II}_6\ Ti_{12}\ O_{33}$ where Y stands for the lanthanons and yttrium. The pure uranium end member may be i. g. $U_2\ Fe^{II}_6\ Ti_{10}\ Fe^{III}_2\ O_{33}$ or $U_{1^1/_2}\ Fe^{II}_6\ Ti_{12}\ O_{33}$ but a further discussion of this problem would seem futile with the data available at present.

A differential analysis of the rare earth content in the Tuftan davidite by O. Joensuu is quoted as note two to table 1., and a graphical representation of this analysis is given in fig. 4. The composition of the rare earths is somewhat unusual as there is a pronounced enrichment of the large as well as the small ions while the content of middlesized ions is exceptionally low. Dixon and Wylie have earlier observed an unusual distribution of the lanthanons in South Australian

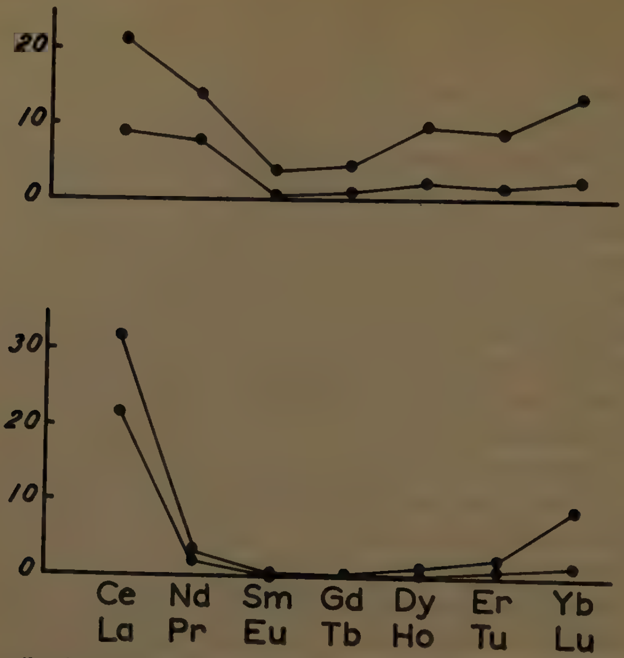

Fig. 4. Distribution of the lanthanons in weight percent of total rare earth oxide contents. Lower curves: davidite, Tuftan. Upper curves: andradite, W. Transbaikal. (8).

davidites (4), and concluded as a probable explanation that "davidite" may not be a well defined mineral, but a complex of more than one mineral species. The authors of the present paper cannot unconditionally accept this explanation, the distribution of the lanthanons in davidite is not in principle any more "abnormal" than for example the distribution of the lanthanons in andradite from skarn in W. Transbaikal examined by Semenov and Barinskii (8), see fig. 4.

Heat-treatment and X-ray pattern.

Unheated metamict davidite gives no X-ray diffractions even with very long exposures. When heated to temperatures between 750°C and 1050°C in air, and to 700°C with a water pressure of 20 000 psi it recrystallizes and gives a characteristic X-ray pattern. The best film was obtained from a run at 1030°C in air for 24 hours and was therefore chosen for measuring the d-values given in Table 2.

d. Å.	I	d. Å.	I	d. Å.	I
3.39	m.	2.47	st.	1.79	m.
3.23	m.	2.41	v. w.	1.69	w.
3.04	w.	2.35	v. w.	1.67	m.
2.88	v. st.	2.23	st.	1.61	v. w.
2.83	w.	2.13	st.	1.59	st.
2.72	v. w.	2.03	v. w.	1.50	w.
2.62	v. w.	1.90	w.	1.43	st.

Table 2. X-ray powder data for davidite from Tuftan, heated in air at 1030°C for 24 hours. Filtered Fe-radiation, camera diameter 9 cm. Intensities visually estimated, v. st. = very strong, st. = strong, m. = medium, w. = weak, v. w. = very weak.

The authors as well as dr. J. E. T. Horne have compared the pattern of davidite from Tuftan with the patterns of davidites from eight different localities. The X-ray diagram of davidite from Tuftan, to quote dr. HORNE (5), "shows a multi-phase pattern in general agreement with those of specimens of davidite, similarly treated", (from other localities). "Perfect agreement is not to be expected in these cases, as minor variations in chemical composition are bound to result in variations in the proportions of the different phases resulting from the heat treatment. The Tuftan pattern agrees as well with the others as they do amongst themselves".

Other Norwegian localities for davidite.

Massive davidite is found in small amounts in a breccia zone in the quarry of Åmot pukkverk in the parish of Modum.

Davidite is also found as an impregnation in a crushed and brecciated zone between a pegmatite and the amphibolitic bedrock north of Bringebærkastet on the island of Langøy east of Kragerø.[4] The narrow brecciated zone is quite strongly radioactive because of the content of davidite.

In both cases davidite was identified in this museum by its characteristic X-ray pattern when heated.

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[4] Viggo Wiik, personal communication.

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Geologisk Museum
University of Oslo, 5th March 1960.

Manuscript received March 10, 1960.

Printed December 1960.

ON THE OCCURRENCE OF KYANITE IN THE ECLOGITES OF THE SELJE AND ÅHEIM DISTRICTS, NORDFJORD

By
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Abstract: Kyanite is recorded for the first time in Norwegian eclogites and localities are indicated. The alteration of kyanite to a corundum-oligoclase kelyphite or to zoisite, during an amphibolite facies metamorphism of eclogite, is briefly described.

Introduction

The field association and mineralogical variations of the eclogites of Sunnmøre and Nordfjord were first described by Eskola (1921). He noted the occurrence of eclogites both as small lenses in amphibolite facies gneisses, and as contorted layers in some of the dunites of Sunnmøre.

The essential minerals of the eclogite facies are garnet, clino-pyroxene, ortho-pyroxene, olivine, kyanite and quartz. Kyanite, however, did not occur in any of the specimens which Eskola studied. In his classic paper he also described the common alteration of eclogite to amphibolite through the development of diopside-plagioclase, or hornblende-plagioclase symplectites from clino-pyroxene, and hornblende kelyphites from garnet.

During the summers of 1958—59 the writer has studied the rocks of the Selje and Åheim districts and has found many kyanite eclogites. The more important localities are indicated in figure 1.

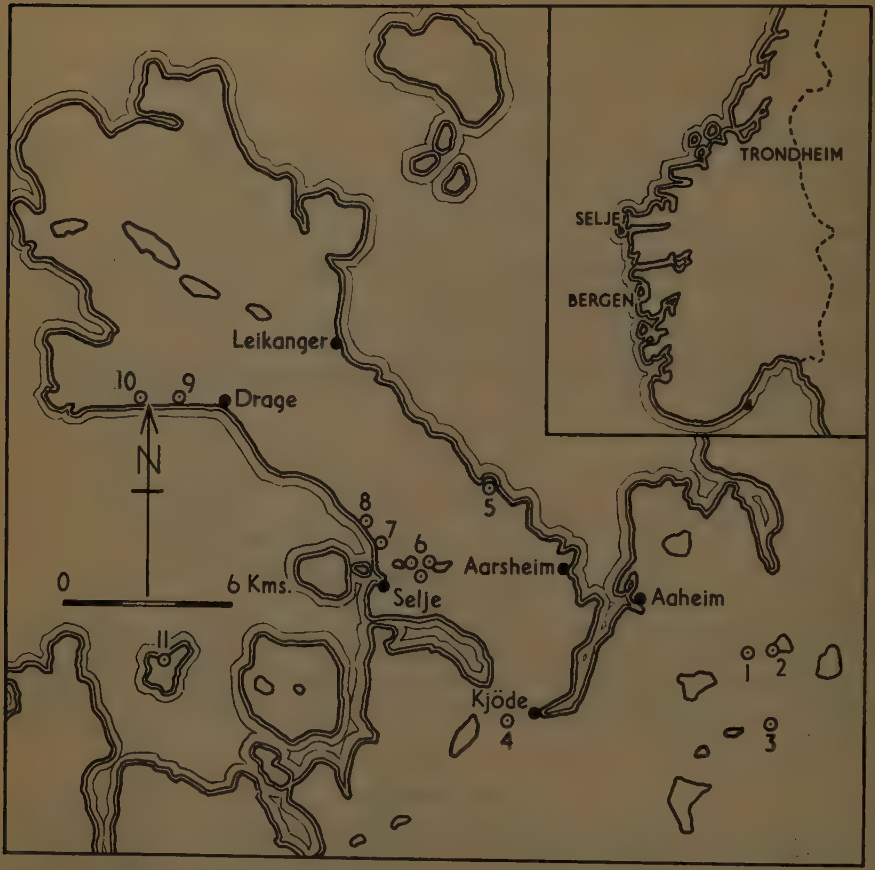

Fig. 1.: LOCALITIES.
1. 400 metres N.E. of Ekremsæter farm, Almklovdal. 2. The south shore of Sæter Vatn, Almklovdal. 3. 300 metres E. of Kasen farm, Almklovdal. 4. 1.25 kms. W.S.W. of Kjøde (zoisite eclogite). 5. Shore section on Sandviknæs, 4 kms. N. E. of Årsheim. 6. A series of small lenses traced from Dybedalsvatn to the small lakes about 1 km. N.W. of Selje. 7. Shore section at Pileberg 1.5 kms. N. of Selje. 8. Shore section between Lisæter and Skorbø, 4 kms. N. of Selje. 9. Shore section 1 km. E. of Drage. 10. Path to indre Fuhre, 4 kms. E. of Drage. 11. North coast of Silden island.

Field Association

Eclogites occur as small lenses in the gneiss and appear to be concentrated along certain structural horizons. Thus, the eclogites of the shore section immediately north of Selje can be traced in the steep east-west limb of a synformal fold as far as Årsheim (fig. 1). Eclogite-bearing horizons also occur in the northern shallow dipping limb (strike N.N.W. — S.S.E.) of this fold and can be seen in a strike section exposed in the cliffs between Selje and Drage. Kyanite eclogites occur in these zones and a series of kyanite-bearing lenses has been traced along the strike for a distance of one kilometer (locality 6. Dybedals Vatn).

Characteristically, kyanite occurs only in lenses of coarse-grained eclogites (garnet between 1 and 1.5 cms. in size) and in the coarser bands of finer grained types. It is usually associated with quartz and has not been seen in the more basic, orthopyroxene eclogites of the gneisses or in the garnet bearing rocks of the dunites. The only stable mineral association is quartz-kyanite-garnet-clinopyroxene. One kyanite-bearing specimen from Silden (locality 11) does not, however, contain quartz. Kyanite rarely forms more than 5 per cent of the rock. It may occasionally be uniformly distributed throughout a lens but is more generally found in apparently random patches or associated with quartz or pyroxene-rich layers. Kyanite is unmistakable in hand specimen for it occurs as interstitial, blue streaks, or as blue, ideomorphic laths up to 8 mms. in length.

The alteration of kyanite

The alteration of kyanite is not widely reported in literature. Tilley (1936) discussed some petrogenetic implications of this problem and concludes that kyanite may be replaced by anorthite (in plagioclase), zoisite or clinozoisite depending on local conditions. He recognises, following Brière (1920) that kyanite eclogites are generally altered to kyanite-free amphibolites without change in bulk composition. These observations apply also to the Norwegian kyanite eclogites where kyanite is completely replaced during amphibolitisation. In partially altered eclogites, however, kyanite is often surrounded by a pale pink reaction rim; or is replaced by a white zoisite. These two types of alteration can generally be observed in one thin section but since they are separated in time and manner of replacement they are described separately.

1. In the first type of alteration a very fine, hair-like kelyphitic rim is developed which consists of small, colourless, lath-like crystals of high refractive index and low birefringence set in a base of plagioclase.

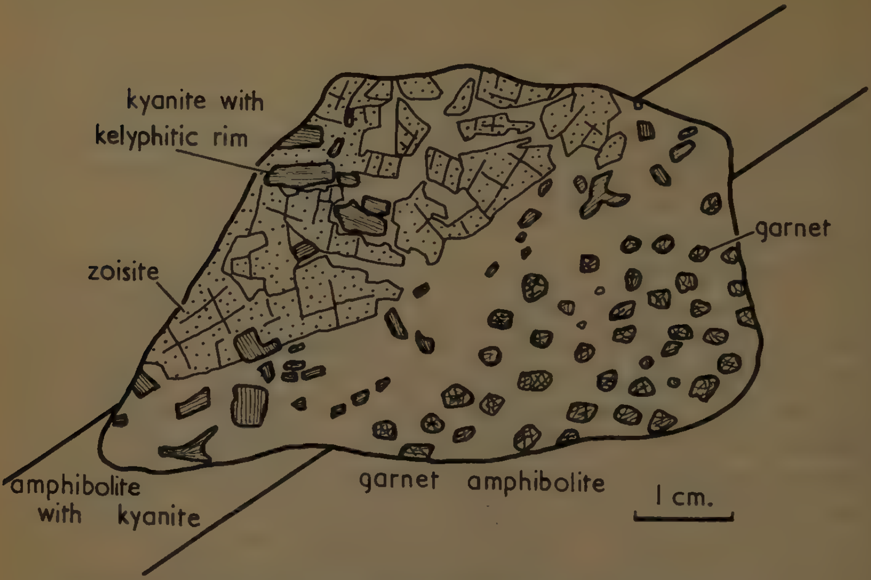

Fig. 2. A cross-section of a kyanite-zoisite vein in a garnet amphibolite (drawn from a photograph).

An X-ray powder photograph of such a pinkish kelyphite indicates a mixture of oligoclase and corundum. All stages of replacement of kyanite by this pervasive kelyphite have been seen. Often some recrystallisation of this kelyphite occurs with the formation of transverse, chain-like aggregates, or larger barrel-shaped crystals, at the flared edges of the kelyphite (plate I, fig. 2 and plate II, fig 1). Available evidence indicates that corundum is unstable in over-saturated rocks. It is only a transient stage in the amphibolitisation of kyanite eclogites as the corundum kelyphite is always surrounded by a wide, clear zone of recrystallised plagioclase (plate 2, fig. 2) and is eventually absorbed in the surrounding hornblende-plagioclase symplectite.

2. The second type of alteration produces white, elongate plates of zoisite which forms streaky aggregates in partially amphibolitised kyanite eclogites. Zoisite occurs only in these rocks and is not a primary mineral of the kyanite eclogites. It must, then, be regarded as a partial replacement of kyanite. In this context two specimens are of special interest.

The first, is a small, irregular vein-like mass in an amphibolitised eclogite lens from Lisæter (locality 7). The field relationships of this

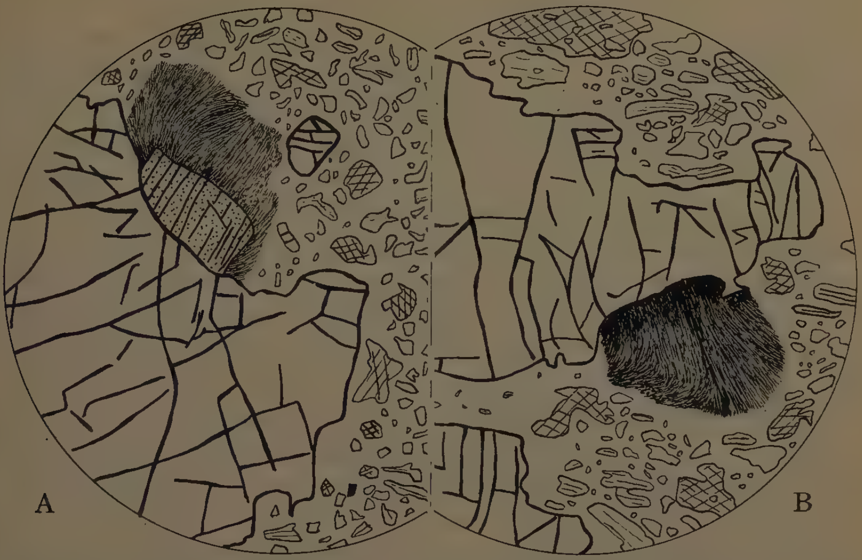

Fig. 3. Large, late zoisite plates cut and replace A) kyanite with its surrounding corundum-plagioclase kelyphite and B) a corundum-plagioclase kelpyhite. Kyanite-zoisite vein in amphibolitised eclogite from locality 7. (× 50).

vein are not clear but it is obviously of replacement origin. The main mass of the vein is made up of pale green plates of zoisite, the individual crystals of which attain dimensions of about 2 cms. by 1 cm. by 0.5 cms. These plates are elongate and striated parallel to the 'b' crystallographic axis. Kyanite, often with a fine corundum bearing kelyphitic rim, occurs as inclusions in zoisite; and at both the ragged edges of the vein and within the immediately surrounding amphibolite (figure 2). Garnet is not seen in a centimetre wide zone around this vein and, since the vein has apparently been developed in a uniform textured eclogite, the garnet must have been absorbed.

The zoisite plates cut across kyanite laths and their surrounding kelyphites and are thus of later origin (figures 3 a & b). The absence of garnet near this vein suggests that zoisite has been formed by a reaction between garnet and kyanite (or its alteration products corundum and plagioclase). Later reactions associated with the final amphibolitisation of the eclogites have resulted in the local replacement of zoisite by muscovite or by another zoisite mineral characterised by anomalous birefringence colours.

The second specimen collected, E.N.E. of Kjøde (locality 4), is a zoisite eclogite which could be compared with the zoisite eclogites of the Fichtelgebirge region, Bavaria. Since this specimen contains only a small amount of kyanite it may be regarded as an extreme variant of the Silberbach zoisite eclogite which was exhaustively described by Wolff (1942).

Zoisite forms up to 10% of the Kjøde specimen and occurs as white, randomly orientated laths up to 3 cms. by 0.2 cms. by 0.1 cms. in size. It contains abundant inclusions of rutile and quartz. The manner in which the zoisites cut through single crystals of both garnet and clino-pyroxene indicates that zoisite has formed later than both these minerals. A few, bladed kyanite crystals have been observed in this lens and it is probable that zoisite is again replacing kyanite. Zoisite laths were not seen in the amphibolitised borders of this eclogite and have probably been replaced during the later amphibolitisation of this body.

X-ray powder photographs and optical data for the three types of zoisite: — from the altered kyanite eclogites, from the kyanite-zoisite vein, and from the zoisite eclogite, indicate that these minerals are identical. The composition can be refered to β zoisite although some of the optical properties are rather anomalous.

The time relationships of the crystallisation of zoisite seem to be variable. In kyanite eclogites it forms after development of the corundum-oligoclase kelyphites but before or during the early stages of amphibolitisation. Zoisite is, however, affected by the amphibolitisation of the zoisite eclogites and in these rocks its crystallisation precedes this phase of the metamorphism.

Conclusions

1. The discovery of kyanite in the eclogites of Nordfjord removes the main anomalous feature of the Norwegian eclogite association. A direct comparison can now be made with the classic eclogite-bearing regions of Germany (Bavaria), Austria (the Tirol and Karnten provinces), and the Alpine regions of Switzerland, France and Italy. In these areas, eclogites occur as lenses or layers in gneisses and schists of various facies, but as in Norway the following mineral associations are characteristic.

quartz – kyanite – garnet – clinopyroxene.
quartz – garnet – clinopyroxene.
garnet – clinopyroxene.
garnet – clinopyroxene – orthopyroxene.

So far as it is known to the writer, Glenelg, Scotland is the only major European locality in which kyanite does not occur.

2. In the early stages of retrogressive metamorphism, kyanite is replaced by a corundum-oligoclase kelyphite. During the amphibolitisation of the eclogites this kelyphite is taken up by the plagioclase of the surrounding plagioclase- hornblende symplectites. β zoisite forms directly from kyanite, and possibly garnet, during amphibolitisation.

3. Zoisite and the amphibole smaragdite have sometimes been considered as primary minerals in the eclogite facies. The main evidence for this view seems to be textural, in that both minerals occur as well formed, randomly orientated laths in granular eclogites. Commonly, also, these minerals are affected by the late amphibolitisation of the eclogites and have, thus, been regarded as an early, and hence, primary phase.

This interpretation does not seem to be valid in the zoisite eclogite described above, even though the zoisite has all the apparent 'primary' characters. It has been demonstrated that zoisite, a) crystallised after both garnet and clino-pyroxene, b) occurs with accessory kyanite, and c) is identical with the zoisite formed by the alteration of kyanite. This porphyroblastic zoisite should also be regarded as a replacement product of kyanite. It is suggested that zoisite, and by analogy, smaragdite are not primary minerals of the eclogite facies, but that their good form and random orientation is a function of local conditions which have allowed recrystallisation. This alteration is not necessarily of different grade to the more common, pervasive alteration (the formation of symplectites and kelyphites) of the eclogite minerals even though they may be separated in time. Local variation in the vapor pressure and the physical properties of the rocks are probably critical factors which determine the course of the alteration processes.

Acknowledgements

This work was done during the tenure of a D.S.I.R. research scholarship. The writer wishes to thank Dr. B. A. O. RANDALL of King's College who has critically read the manuscript and made many helpful suggestions.

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Manuscript received April 21, 1960
Printed December 1960

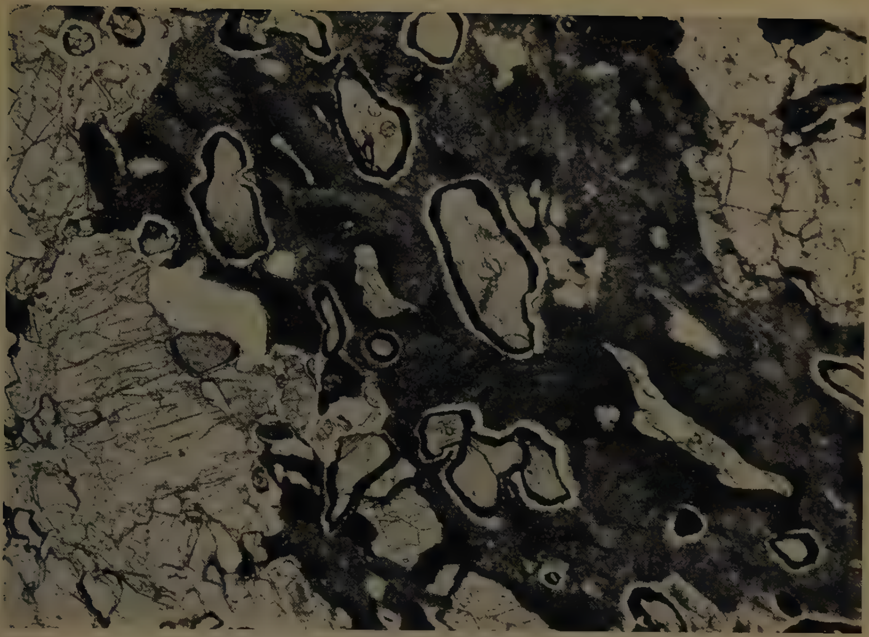

Fig. 1. Kyanite laths surrounded by an inner corundum and an outer plagioclase zone, the laths are set in a finely crystalline diopside-plagioclase symplectite which is the result of the alteration of a pyroxene rich layer. Foliated garnets and zoisite occur in the east and west fields. (locality 1). (×30).

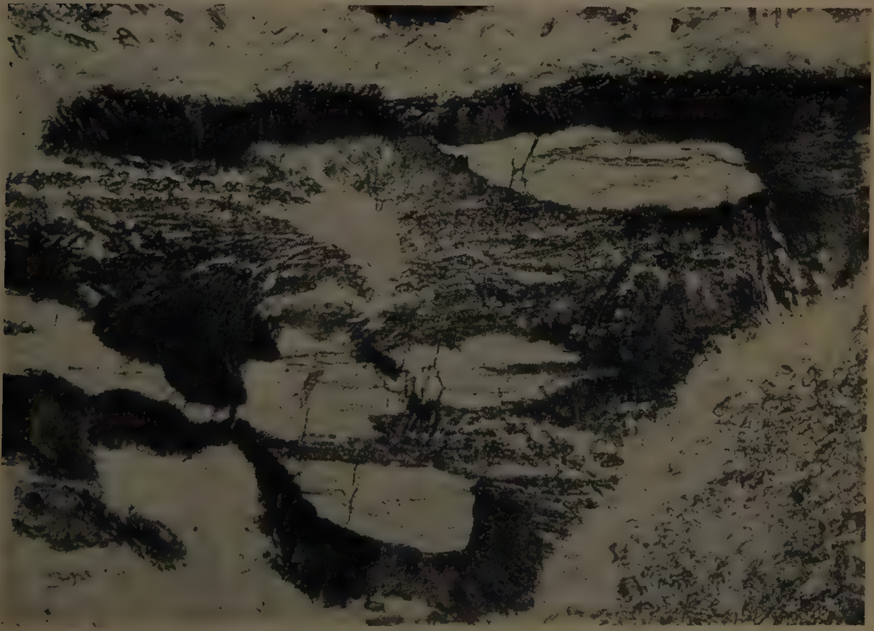

Fig. 2. A large kyanite which shows replacement by a fine, hair-like corundum-plagioclase kelyphite. This kelyphite recrystallises into larger crystals which form transverse aggregates. (locality 7). (×30).

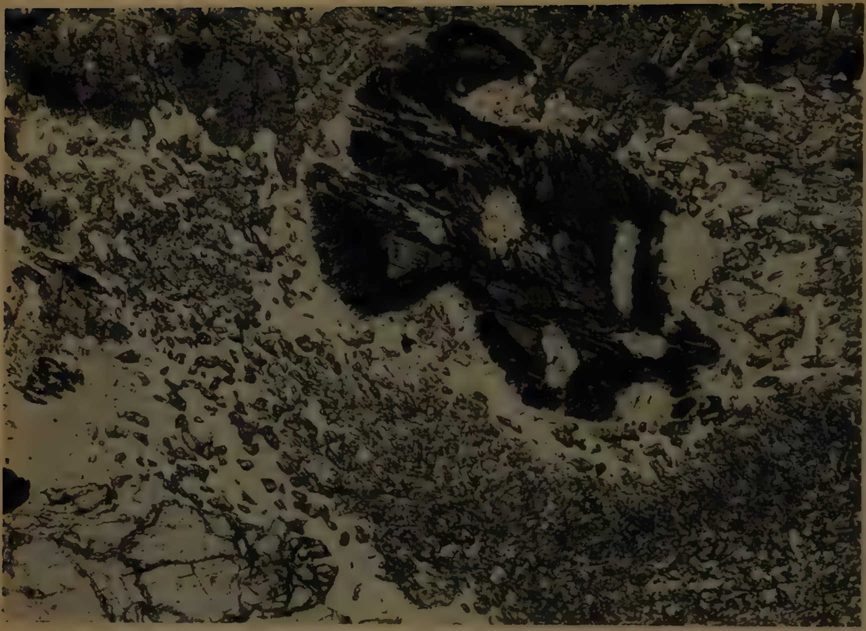

Fig. 1. A corundum-plagioclase kelyphite cored by residual kyanite set in a locally recrystallised hornblende-plagioclase symplectite. Note the plagioclase zone around the kelyphite and the large zoisite in the lower field (locality 7). (×30).

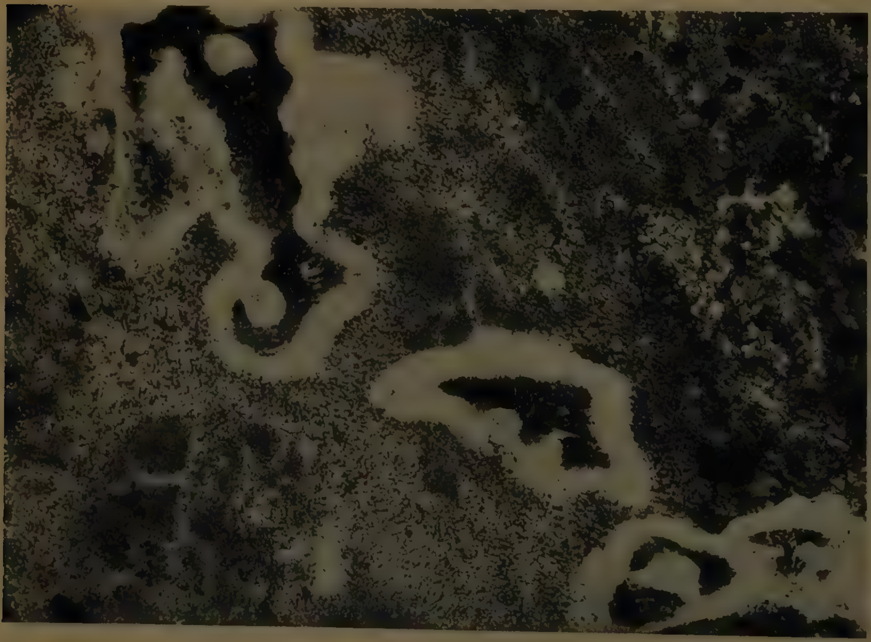

Fig. 2. A corundum-plagioclase kelyphite with rather lobate boundaries due to replacement by plagioclase. The kelyphite is surrounded by a wide zone of recrystallised plagioclase, the main groundmass is a fine grained amphibolite (locality 6). (×30).

K. O. Bjørlykke

1860—1946

Minnetale i Norsk geologisk forening på møte 11. februar 1960.

Av Gunnar Holmsen.

Idag er det 100 år siden professor ved Norges Landbrukshøgskole, dr. philos. Knut Olai Bjørlykke ble født i Sande, Sunnmøre.

Han ble med i den generasjon av banebrytende geologer, i hvis spor den unge geologiske forskning i vårt land lenge skulle følge. Disse geologers virke omfattet alle geologiens bransjer, og hele landet utgjorde deres arbeidsområde. Bjørlykke var kanskje den av dem, hvis navn var mest kjent utover landet. Så vel hans mange reiser som hans mangeårige undervisning på Landbrukshøgskolen førte det med seg. Han fikk elever fra landsende til annen, et rikt utvalg av medarbeidere, som han satte til å beskrive geologiske detaljer på hjemstedet. Mange av disse er trykt i en serie jordbunnsbeskrivelser utgitt av Det kgl. Selskab f. Norges Vel. Hvorsomhelst en geolog har arbeide fore i vårt utstrakte land vil han den dag i dag kunne møte en av dem, som har fått sin naturvitenskapelige interesse vakt under Bjørlykkes veiledning.

De fleste av Bjørlykkes generasjon var uoppslitelig ærlige i sin innsats så vel for sitt samfunn som for sin vitenskap. De måtte, mere enn nå er tilfellet, på egen hånd finne frem i sitt fag. Ved universitetet var det den gang mindre av spesialkurser enn det nå er. I naturfagene var det imidlertid ekskursjoner hvorunder studentene fikk sikre, om enn ikke så omfattende kunnskaper. Kanskje var det dette, som førte til at diskusjonsinnleggene mellom geologer den gang var mere tilspisset enn de senere ble. I motsetning til flere av hans kolleger tillot Bjørlykke seg i allfall i sine skriftlige innlegg, som er oppbevart, aldrig en frihet utenfor det akademisk sømmelige, og hans sprog er klart og velpleiet, så en aldri er i tvil om hans mening. Hans tørrvittige ironi like overfor svada fra elevenes side kunne svi, herom vet mange av hans gamle elever noe å berette. Men bak hans tilknappete maske banket et varmt hjerte for elevenes ve og vel.

Bjørlykkes produktive forfattervirksomhet strakte seg over mere enn et halvt sekel. Utenom det rent vitenskapelige forfatterskap la han megen vekt på å spre kunnskap om sitt fag i populær form gjennom artikler i tidsskrifter og dagspressen.

K. O. Bjørlykke begynte som så mange andre landsgutter sin boklige løpebane på lærerskole. 18 år gammel gikk han ut fra Asker lærerseminar, og ernærte seg som lærer i hjembygden et par år. Så reiste han til Kristiania, hvor han tok realartium i 1882, studerte, og ble cand. real. 1889 med gruppene matematikk-astronomi, og naturfaggruppen. Som student tok han del i professor Kjerulfs tennende undervisning i geologi og mineralogi og fikk sin interesse for disse fag næret under Kjerulfs kateter. I sine skrifter kommer han flere ganger tilbake til dette. Som kandidat var han en tid lærer ved forskjellige skoler i Kristiania.

Hans geologiske debut fant sted 1891 da han ved nyfunn av forsteninger i Gausdal kunne fastslå et sikkert utgangspunkt for den geologiske aldersfølge av bergartene her. En avhandling om betydningen av dette funn lot han trykke i det første skrift av Norges geologiske undersøkelses publikasjoner, Årbok, utgitt av daværende bestyrer dr. Reusch. Den ble fulgt av 2 andre avhandlinger om fjellbygningen i Gausdal-området. I Norges geologiske undersøkelses skrifter så vel som i Norsk Geologisk Tidsskrift finner vi de fleste av hans geologiske arbeider trykt eftersom de ble skrevet. Et par mindre meddelelser fra de samme år, Om plante- og dyrefossiler i leir, og Om den eiendommelige jordart «kvabb» er trykt henholdsvis i «Naturen», hvortil han sendte mange populære meddelelser og i Tidsskrift for landbruk, hvori vi finner så mange av hans avhandlinger innenfor jordbunnslæren.

I begynnelsen av 90-årene reiste han også med offentlig stipendium til Heidelberg og München for sin utdannelses skyld. I 1895 ble han hjelpegeolog ved Norges geologiske undersøkelse, ett år (1897—1898) endog konstituert bestyrer. Fra 1898 ansattes han som lærer ved Ås høiere landbruksskole, som senere ble til Norges Landbrukshøgskole.

Så lenge han bodde i Kristiania gjorde han omfattende iakttagelser over byens berg- og leirgrunn, og tok sikte på å besvare en prisoppgave fremsatt for perioden 1893—1894 av Universitetets matematisk-naturvitenskapelige fakultet av følgende ordlyd:

«Der forlanges med benyttelse av forhåndenværende topografisk underlag et geologisk kart over Kristiania bys territorium i målestokk mindst 1 : 12 000. Aflæg på et eksemplar af kartet de steder, hvor vedkommende bergart, formation og etage er iagttaget, og vis på et andet eksemplar den sandsynlige utbredelse af vedkommende bergart, formation og etage under den bebyggede eller dyrkede del af byens territorium.»

Som bedømmelseskomite for denne meget krevende oppgave ble oppnevnt professorene A. Helland, J. H. L. Vogt og W. C. Brøgger. Som følge av komiteens uttalelse besluttet kollegiet, at forfatteren med Motto «Die Kristiania-Gegend giebt den Schlüssel zu der Geologie von Norwegen», Knut Olai Bjørlykke, skulle tilkjennes prisen, som bestod i kronprins Gustaf Adolfs gullmedalje.

Bjørlykkes manuskriptkart ble smukt trykt i mange farver og utgitt 1898 ledsaget av en rikelig illustrert, forklarende tekst på 86 sider. Det er et mønster for alle tider på nøyaktig geologisk kartlegging, og det har hatt den største betydning for kjennskapet til byens byggegrunn helt til dags datum. Dets kapasitet er imidlertid større enn første blikk på kartet viser, og W. C. Brøgger mente, at byreguleringen ikke fullt ut hadde forstått å nyttiggjøre seg det. Tungbebyggelse, som krever god byggegrunn skulle fortrinsvis være lagt på bergunderlag, sa han, mens plasser, parker og lette hus kunne plaseres over de leirfylte dyprenner.

Som allerede nevnt kom Bjørlykke til Ås i 1898. Året i forveien hadde Stortinget vedtatt, at skolen skulle utvides og omordnes. Dette medførte for Bjørlykkes vedkommende planleggelse og tilsyn med nybygging av et geologisk institutt med samlinger, laboratorier og bibliotek, og under hans ledelse vokste dette opp til en betydelig institusjon, som foruten undervisningsmateriell består av bergart- og mineralsamlinger, fossiler samt en stor samling jordprøver og jordprofiler, ordnet fylkesvis, fra det hele land. Dette velordnete institutt har vakt beundring fra alle hold. Å få istand dette sammen med en omfattende undervisning i mineralogi, geologi, zoologi og senere jordbunnslære vitner om Bjørlykkes store arbeidsevne, og dertil kommer, at han nettopp i denne grunnleggelsens tid på Landbrukshøgskolen foretok overmåte anstrengende vandringer i vårt høyfjell, hvorunder han samlet materiale til sin banebrytende avhandling, *Det centrale Norges fjeldbygning*, som utkom 1905 og ble hans doktorarbeide. Avhandlingen inneholder iakttagelser over bergbyggingen i en sådan mengde, at den fremdeles er den viktigste oppslagsbok i det emne tittelen angir. Bjørlykke hadde tidligere, 1901, sluttet seg til den for geologer så betydningsfulle overskyvningsteori fremsatt av svensken Törnebohm, men tok en viss avstand fra den i doktoravhandlingen. Merkelig nok synes denne nå så aktuelle teori ikke å ha vært diskutert under doktordisputasen.

I 1905 ble Bjørlykke overlærer ved Ås høyere landbruksskole, og ved overgangen av denne til Norges Landbrukshøgskole ble han 1915 utnevnt til professor i mineralogi, geologi og jordbunnslære.

Etter at han hadde utgitt sitt store arbeide om bergbygningen i det centrale Norge konsentrerte han seg om kvartærgeologiske oppgaver. I 1908 skrev han «Jæderens Geologi» og i 1913 kom boken «Norges Kvartærgeologi», som gir en oversikt over hva de forskjellige norske forfattere hadde bidratt til belysning av denne del av geologien. Dertil har boken en sammenfatning av hva man på den tid visste om kvartærtidens dannelser i Norge.

Etter Bjørlykkes initiativ opprettet Det kgl. Selskap f. Norges Vel i 1908 et jordbunnsutvalg, hvis formann Bjørlykke var hele tiden inntil 1921 da det ble knyttet til Landbrukshøgskolen under navn av «Statens Jordundersøkelse».

Bjørlykkes arbeide med organisasjonen av de vitenskapelige jordundersøkelser er av særlig betydning, idet grunnvollen til jordbunnslærens innførelse ved Høgskolen derved ble lagt. Han fulgte intenst med i fagets utvikling ute i den store verden, og møtte frem ved alle viktige internasjonale jordbunnskongresser medbringende iakttagelser fra sitt eget land, som vakte stor oppmerksomhet, og tok med tilbake fruktbringende impulser. Således reiste han til Finland og Rusland 1902, til Danmark og Nord-Tyskland 1905, England 1907, Ungarn 1909, Sverige 1910, Tyskland 1914, Danmark og Sønderjylland 1918 og 1921, Tsjekko-Slovakia 1922, Sverige 1923, Italie 1924, USA og Canada 1927, Tyskland og Finland 1929. Han har selv gitt referat av sine studiereiser til de fleste europeiske land og til USA. De er å finne frem til ved hjelp av den medfølgende bibliografi.

«Vitenskapen om jorden har gjort betydelige fremskritt i de siste 20 år», skriver Bjørlykke i 1922. «Jordbunnstudiet må nå oppfattes som en selvstendig gren av naturvitenskapen, jordlære eller pedologi, sidestillet med dyrelæren eller zoologi, plantelæren eller botanikk og stenlæren eller geologi. Vi må utskille og beskrive våre forskjellige jordarttyper således at vi får klart for oss jordartene før vi kan bygge opp en klassifikasjon.» — Det var denne erkjennelse han viet sin største oppmerksomhet under sitt virke som forsker og underviser på Landbrukshøgskolen. Han begynte med å vise, at vi også i vårt land har jordarter, som dannes i et tørt, et arid, klima. Fra Gudbrandsdalens nedbørfattige områder, Sjåk og Lom, beskrev han en hvit skorpe av svovelsure salter, «saltbitterjorden», som der krystalliserer ut på tørre bakkers gressvoll. Fra Vingelen og Rørostrakten beskrev han kalkskorper, som dannes i sandjord under overflaten i likhet med aurhelle.

Av hensyn til bureisingen var det et meget viktig spørsmål om vi kunne få vite *hvor* vi har de store dyrkningsvidder «alle taler om», sier han spydig, «hvad vet vi egentlig om dem?» Han forsøkte å lage et oversiktskart over de løse jordlag i Norge, men det ble ikke så godt som han ønsket, og han ble ikke tilfreds med det. Vi hadde ikke nok opplysninger om jordlagene i vårt land. Han henstilte derfor til Norges geologiske undersøkelse i 1932 å fremstille et oversiktskart utarbeidet etter geologiske inndelingsprinsipper med det formål å gi en oversikt over den rolle jordartene spiller i vårt lands økonomiske liv. Et kvartærgeologisk kartverk er påkrevet for at vi kan lære å kjenne og demonstrere vårt lands jordrikdom, «eller kanskje rettere jordfattigdom» sier han. Hans mening er, at det er en ufravikelig betingelse for jordbunnsundersøkelser å ta kartleggingen til hjelp, for selv om et oversiktskart blir noe skjematisert vil det være tilstrekkelig at det gir de store linjer vi ennå mangler. De rent agronomiske spørsmål mente han skulle overlates til «Statens Jordundersøkelse».

Denne pekepinn tok Norges geologiske undersøkelse seg ad notam, og startet et par år senere begyndelsen av et kvartærgeologisk kartverk i målestokk 1 : 250 000, hvorav nå det meste av det østenfjeldske Norge er utgitt.

I diskusjonen om årsakene til husbeskadigelsene langs Holmenkollbanens tunneltracé i Kristiania deltok mannsterkt så vel norske ingeniører som norske vitenskapsmenn, blandt de siste både geologer og fysikere. Diskusjonen pågikk i mange år, mellom 1914 og 1928, for det meste skriftlig, og et kardinalpunkt var om den vannmengde, som fra leiret kunne finne avløp til tunnellen var stor nok til å erstatte markens synkning. Dette var i geoteknikkens barndom da porevanntrykkets betydning for leirets kompressjon ennå var upåaktet her til lands. Bjørlykke skrev mange innlegg og kritiserte sterkt de forskjellige «beviser» som ble fremlagt som fullgydlig forklaring på tunnellens skyld i husenes sprekkedannelse, og det med rette. Meget av det materiale, som ble fremlagt under prosessen var av underordnet betydning, og noe var til dels tvetydig. Om det enn ikke på den tid lykkedes hverken ham eller noen annen av dem, som deltok i diskusjonen å gi en klar formulering av hva i geoteknisk terminologi nå kalles for setningsproblemet, var hans innsats i saken betydningsfull gjennom kritikk han rettet mot manglende undersøkelser og uholdbare antagelser.

Det siste store arbeide Bjørlykke utga heter «Utsyn over Norges Jord og Jordsmon». Det ble trykt i 1940. Som tittelen angir, og som han selv skriver i forordet har han her som avslutning på en lang arbeidsdag samlet og ordnet sine iakttagelser fra hele landet hvad jordbunn, jordarter og jordsmon angår. Boken har som tillegg en verdifull liste omfattende henimot 200 større eller mindre avhandlinger om norsk jordbunnslitteratur helt fra år 1924 til 1939.

Bjørlykke utga flere meget anvendte lærebøker. Først skal nevnes en illustrert skoleflora «Norske Planter» med 1ste utgave 1892 og siste (11te) så sent som i 1958. Siden kom «Liten Skoleflora» i 1929, rikt forsynt med bilder. Meget brukt av geologistuderende er hans «Geologi eller Læren om Jorden», også i mange opplag, det siste i 1946, noe omarbeidet av sønnen dr. Harald Bjørlykke. En annen, mere elementær lærebok «Om stenene og Jordbunnen» har i årene fra 1906 til 1946 blitt trykt i 5 opplag.

Her i Norsk geologisk Forening minnes vi Bjørlykke som en av foreningens stiftere. Foreningens tilblivelseshistorie er omtalt i Norsk Geologisk Tidsskrift B I. Foreningen hadde en forløper i «Den geologiske klub», en sammenslutning av geologisk interesserte herrer i Kristiania som møttes noen ganger i vinterens løp til foredrag og diskusjon. Det første møte ble holdt 2. mars 1893. Klubben hadde intet budsjett, ingen skreven lov, ingen medlemskontingent og heller intet styre, men den måtte ha en sekretær for å ordne med møtene, og til sekretær ble valgt cand. real. K. O. Bjørlykke. — I møtet 18. okt. 1895 fremsatte sekretæren forslag om, således som det var forutsatt ved klubbens dannelse, at den burde organiseres som forening. Dette vant ikke bifall av Brøgger, Reusch, Vogt og flere, som fant ordningen med en klubb tilfredsstillende som det var, og så ble det ikke snakket mere om noen forening før i 1903. Da ble man enig om at en sådan skulle dannes, og en komite til utredning av saken ble oppnevnt. Imidlertid hadde Bjørlykke, som det fremgår av beretningen, i alle disse klubbens år vært en av støttene for å holde liv i den med foredrag og diskusjonsinnlegg. Først på møte 18. febr. 1905 konstituerte seg Norsk Geologisk Forening med lover, medlemskontingent og utsikt til et årlig bidrag fra Nansenfondet på 250 kr. Der skulle holdes minst 4 møter om året.

Møtestedet ble i Den geologiske undersøkelses lokaler. Utstyret var så enkelt, at de fremmøtte måtte selv bære sine stoler fra kontorene til foredragsrummet, der som regel var biblioteket.

Innen sitt fag inntok Bjørlykke en bred plass i samfunnet. Han var formann i den departementale nydyrkningskomite av 1918, medlem av kommisjonen for økonomisk oppmåling av landet 1919—1924, formann i styret for den norske seksjon av det internasjonale jordbunnsselskap 1925—1931, medlem av Nordiske jordbruksforskeres forenings jordbunnsseksjon og deltager i dens møter i Kjøbenhavn 1921, Gøteborg 1923, Oslo 1926 og Helsingfors 1929.

Bjørlykke vokste opp i en tid med brytninger og sterke meningsytringer blant førere av store dimensjoner, i politikk så vel som i kunst og naturvitenskap, og han var preget derav. Hans venn og elev, skolebestyrer Dietrichson, fremhevet ved avsløringen av Bjørlykkes maleri på hans 80-årsdag det særpregete ved ham, først og fremst hans selvstendighet, og karakteriserte ham som et ektefødt barn av en tid med sterke personligheter, av en tid, da menneskene fikk anledning til å ta sin plass i samfunnet som individer.

Bjørlykke var medlem av Det Norske Vitenskapsakademi siden 1902 og av representantskapet i Det kgl. Selskap f. Norges Vel siden 1927.

Han døde 26. febr. 1946.

K. O. Bjørlykkes publikasjoner

Av bibliotekar Karin Hjeltnes.

(NLH — Norges landbrukshøgskoles beretning).
(MNLH — Meldinger fra Norges landbrukshøgskole).
(NJF — Nordisk jordbruksforskning).

1890 Geometrisk opgavebog. 100 opgaver samlet og ordnet til brug for pigeskoler, borgerskoler og middelskoler af ... H. 1—2. Chra.

1891 Beyers turist- og kontor-kart over Norge. 1 : 800 000, udarb. ved N. N. Sontum. 2. opl. i 2 bl., corrigeret ved K. O. Bjørlykke. Bergen.

— Graptolitførende skifere i vestre Gausdal. (NGU [1], 1—10). Også i særtr.

1892 Norske planter. En skoleflora med billeder. Chra. XII, 120 s.

— Praktiske fortegninger. 1ste række. 48 frihåndsfortegninger for begyndere til brug i folkeskoler og middelskoler. Tabel 1—48. Chra.

1893 Gausdal. Fjeldbygningen inden rektangelkartet Gausdals omraade. Chra. 36 s. (NGU 13).

— Den norske nordpolsekspedition ved dr. Fridtjof Nansen. (Det norske geogr. selsk. aarbog, *4*, 1892/93, 86—92). Også i særtr.

— Postglaciale plantefossiler. (Naturen, *17*, 51—54). Også i særtr.

— Skredet i Værdalen. (Det norske geogr. selsk. aarbog, *4*, 1892/93, 105—12). Også i særtr.

1894 Høifjeldskvartsens nordøstligste udbredelse. (NGU 14, 60—75). Også i særtr.

— Svar til dr. Törnebohm om kalkstenen ved Baalsæter. (Geol. för. i Stockholm. Förh. *16*, 64—66). Også i særtr.

1896 Et besøg i Kolbermoors Torvfabrik. (Norsk landm.bl. *15*, 372—73).

1896 Krabb. [ɔ : Kvabb.] En egen jordart i det centrale Norge. Iagttagelser gjorte for Norges geologiske undersøgelse. (T. norske landbr. *3*, 82—87). Også i særtr.

1897 Geologiske billeder fra Kristiania by. Foredrag. (Det norske geogr. selsk. aarbog, *8*, 1896/97, 77—113).

— Geometrisk opgavebog. 100 opgaver samlet og ordnet til brug for pigeskoler, borgerskoler og middelskoler af ... H. 1. 2. opl. Kra.

— Norske planter. En skoleflora med billeder og med en kortfattet plantelære. 2. utg. Kra. XIV, 162 s.

1898 Geologisk kart med beskrivelse over Kristiania by. Kra. VII, 86 s. (NGU 25).

— Norges geologiske undersøgelses udstilling i Bergen 1898. Kra. 83 s. (NGU 26).

— Om øiegneisen i Formokampen, Gudbrandsdalen. (Skand. naturforsk. möte, 15, Sth. 1898. Förh., 218—21). Også i særtr.

1899 Om geologisk-agronomiske karter. (T. norske landbr. *6*, 274—80). Også i særtr.

1900 Geometrisk opgavebog. 100 opgaver samlet og ordnet til brug for pigeskoler, borgerskoler og middelskoler af ... H. 2. 2. opl. Kra.

— Glaciale plantefossiler. (Naturen, *24*, 39—44).

— Lidt om Aas-moræneneņ. (T. norske landbr. *7*, 12—20). Også i særtr.

— Plan for jordartsundersøgelser og jordbundskarter. (T. norske landbr. *7*, 558—69). Også i særtr.

— Stipendieberetning om mineralogi, geologi og jordbundslære som undervisningsfag ved en del af udlandets høiere læreanstalter for landbrug og skogbrug. (NLH, 1898/99, 41—58). Også i særtr.

1901 Om jordbunden i Solør. (T. norske landbr. *8*, 604—13). Også i særtr.

— Overskyvninger i den norske fjeldkjæde. (Naturen, *25*, 145—52). Også i særtr.

1902 Fra Hardangervidden. III. (NGU 34. No. 2, s. 51—76). Også i særtr.

— Lærebog i geologi med mineralogi og bergartslære. Kra. 224 s.

— Lærebog i mineralogi og petrografi. Kra. 103 s. Særtr. av Lærebog i geologi.

— De nordiske lersorter og deres oprindelse. Foredrag. (Tekn. ugebl. *20*, 166—68).

— Om jordarternes klassifikation. Foredrag. (NLH, 1901/02, E. Tillæg. Norges landbrukshøiskoles skr. 1. 38 s.)

1903 Jordbundsundersøgelser i Rusland; indberetning fra en stipendiereise. (NLH, 1902/03, 124—31). Også i særtr.

— Om jordbunden i skogen. (Forstligt tidsskr. *2*, 3—13, 35—50). Også i særtr.

— Om oversiluren i Brumunddalen. (NGU 37. Nr. 2. 17 s.). Også i særtr.

1904 Et kort tilsvar til dr. J. Kiærs bemærkninger om oversiluren i Brumunddalen. (NGU 37. Nr. 8. 7 s.). Også i særtr.

— Norske planter. En skoleflora med billeder og med en kortfattet plantelære. 3. utg. Kra. 184 s.

1904 Om jordbundsforholdene i Norge; en kort oversigt. (T. norske landbr. *11*, 319—32). Også i særtr.

1905 Det centrale Norges fjeldbygning. Kra. 595 s. (NGU 39). Doktoravh.

— Om ra'ernes bygning. (NGU 43. Nr. 2. 20 s.). Også i særtr.

— Om Selsmyrene og Lesjesandene. (NGU 43. I. 22 s.). Også i særtr.

— Om skogjordbunden. (Fra Skogmødet paa Rena ... 1904. Samtlige afholdte foredrag. Udg. ved Hedemarkens amtsskogselskab, s. 20—29).

— On the geology of Central Norge. A summary of a larger work: «Det centrale Norges fjeldbygning.» Kra. 27 s.

1906 Beretning fra ... om en stipendiereise i Jylland og Nordtyskland for at studere ahldannelse og nyere fremskridt paa jordbundslærens omraade. (Aarsberetn. ang. de off. foranstaltn. t. landbrugets fremme, 1905. III. Stipendieberetn., s. 14—24).

— Kortfattet jordbundslære. Kra. 51 s. Særtr. av Liden lærebog i mineralogi.

— Liden lærebog i mineralogi og geologi. Kra. 83 s. Særtr. av Om stenene og jordbunden.

— Om stenene og jordbunden. Kortfattet lærebog i geologi og jordbundslære særlig for landbrugsskoler. Kra. 138 s.

1907 Istiden i Nordeuropa. (Naturen, *31*, 194—210). Også i særtr.

— Om jordbundens betydning i landbruget. Foredrag. (T. norske landbr. *14*, 89—103). Også i særtr.

— Om smaabrugsloven i England. (T. norske landbr. *14*, 470—75). Utdrag av en beretning til Landbruksdep. om en stipendiereise i England høsten 1907. Også i særtr.

— Pedologiens maal og midler. (T. norske landbr. *14*, 225—38). Også i særtr.

1908 En amerikansk metode til bestemmelse av jordarters gjødningsbehov. (T. norske landbr. *15*, 190—94).

— Jordartsundersøkelse I. (T. norske landbr. *15*, 496—504). Også i særtr.

— Jæderens geologi. Kra. 160 s. (NGU 48).

— Et par nye fossilfund. (Norsk geol. t. *1*, nr. 10. 10 s.). Også i særtr.

1909 Agrogeologi. Beretning fra den 1ste Internationale agrogeologiske konferanse i Budapest 1909. Kra. 56 s. (Jordbundsutv. smaaskr. 3, NLH, 1908/09, D. Tillæg. Norges landbrukshøiskoles skr. Nr. 1).

— Beretning fra ... om en stipendiereise til England for at studere engelske jordbundsforhold, forsøksresultater og metoder for jordens behandling og opdyrkning. (Aarsberetn. om de off. foranstaltn. t. landbrukets fremme. 1908. Stipendieberetn. s. 1—21). Også i særtr.

— Die Bodenverhältnisse in Norwegen. (Conf. internat. agrogéol., 1. Budapest 1909. Comptes rendus, s. 115—22). Også i særtr.

— Helleristning ved Frones i Ullensvang. (Naturen, *33*, 82—84).

— Jordartsundersøkelse II. (T. norske landbr. *16*, 453—67). Også i særtr.

— Norsk geologisk forenings historie og virksomhet til utgangen av 1909. Ved K. O. Bjørlykke og J. Schetelig. (Norsk geol. t. *1*, nr. 13, 60 s.). Også i særtr.

1909 Om jordbund og jordartstyper. (I Otte foredrag fra gaardbrukerkurset ved Norges landbrukshøiskole ... 1909, s. 5—13). Også i særtr.

— Om torvstrø og torvstrølag i de forskjellige amter samt om bruken av andre strømidler, gjødselblandinger og jordforbedringsmidler i Norge i 1908. Beretninger fra amtsagronomerne. [Utg. av K. O. Bjørlykke.] Kra. 119 s. (Jordbundsutv. smaaskr. 2).

— Plan og veiledning for agronomiske jordartsundersøkelser. Kra. 13 s. (Jordbundsutv. smaaskr. 1, T. norske landbr. *16*, 77—87).

— Skogsaken. Noen «kritiske» bemerkninger. (T. skogbruk, *17*, 6—13).

1910 «Fjeldproblemets» stilling i Norge og Sverige ved utgangen av 1909. (Norsk geol. t. *2*, nr. 1, 20 s.). Også i særtr.

— Lærebog i geologi med mineralogi og bergartslære. 2. utg. Kra. 236 s.

— Om kolloidstoffene og deres optræden i akerjorden. Efter docent F. Cornu. (Naturen, *34*, 51—56).

1911 En «hardpan»-dannelse i Norge — i arid klima. (Norsk geol. t. *2*, nr. 5, 12 s.).

— Skal der komme orden i vore økonomiske maalinger? En forestilling til Stortinget. Undertegnet av K. O. Bjørlykke m. fl. (T. norske utskiftn.-væsen, *4*, 104—12).

— Utrasningen ved Haga, nær Hougsund, Øvre Eker. (Tekn. ukebl. *29*, 15—16). Også i særtr.

— Über agrogeologische Kartierung. Sth. (Internat. agrogeol. Konf. 2, Sth. 1910. Verhandl., s. 290—96). Også i særtr.

1912 Liden lærebog i mineralogi og geologi. 2. opl. Kra. 83 s.

— Moderne jordbundsgranskning. Foredrag. Kra. 60 s. (Jordbundsutv. smaaskr. 5).

— Norske planter; en skoleflora med billeder og med en kortfattet plantelære. 4. utg. Kra. XII, 112 s.

— Om grytehol og pytflatedannelse paa Romerike. Kra. 14 s. (Vidensk.selsk. i Kra. Skr. I. Mat.-naturv. klasse 1912. Nr. 4).

— Om jordsmonnet. Kra. 1912. 112 spalter. Særtr. av Landbruksboken. Red.: N. Ødegaard, B. 1, sp. 1—107. Utgitt i 1919.

— Om stenene og jordbunden. Kortfattet lærebog i geologi og jordbundslære særlig for landbrugsskoler. Med 123 billeder. 2. opl. Kra. 139 s.

— En protest. (Ukeskr. landbruk, *2*, 403).

1913 Fundet av en halshvirvel av moskusokse ved Ausberg i Indset. (Naturen, *37*, 282—86).

— Jordbundsbeskrivelse og jordbundskartlægning. (T. norske landbr. *20*, 231—33).

— Norges kvartærgeologi; en oversigt. Med bidrag av O. Nordgaard. Kra. 269 s. (NGU 65).

— Sandfyk og sandslit; en iagttagelse fra Kvitsanden ved Røros. (Naturen, *37*, 80—87). Også i særtr. 7 s.

— Undergrunden i Kristiania. (Tekn. ukebl. *31*, 461—64).

1914 Havler og moræne, spredte træk om lagningsforholdene. (Norsk geol. t. *3*, nr. 2, 24 s.). Også i særtr.

1914 Kalk og mergel. Forekomst og anvendelse i landbruket samt beretninger fra amtsagronomer om kalkspørsmaalets stilling i de forskjellige landsdeler. Kra. 48 s. (Jordbundsutv. smaaskr. 7).

— Om undergrundsbanen og aarsaken til sprækkedannelsen i husene i Kristiania by. [I.] Kra. 110 s.

— Om aarsakene til sprækkedannelse i husene i Kristiania by. (Tekn. ukebl. *32*, 620—22).

1915 Syversrudbankingen og sprækkedannelsen i husene i Kristiania by som eksempler paa psykiske fænomener inden naturvidenskapen. (Naturen, *39*, 57—62).

— Über frühere und gegenwärtige Bodenuntersuchungen in Norwegen. (Internat. Mitt. Bodenkunde, *5*, 113—26). Også i særtr.

1916 Bemerkninger til Rekstads og Hansens personlige polemik. (Norsk geol. t. *3*, nr. 10, s. 95—99).

— Jordbunden paa Romerike; tekst til jordbundskart over øvre og midtre Romerike (kartbladet Nannestad). Kra. 112 s. (Jordbundsbeskr. 14).

1917 De geologiske forhold i Trysil og tilgrænsende trakter. (I Rena—Trysilbanen og Rena kanal. Utarb. ved den av herrederne nedsatte fælleskomite., s. 92—103).

— Jorddyrkning i Norge, specielt i aarene 1914 og 1915. Ved K. O. Bjørlykke og Ingv. Grande. Kra. 78 s. (Jordbundsutv. smaaskr. 9).

— En ny Rudmadal. (I Rena—Trysilbanen og Rena kanal. Utarb. ved den av herrederne nedsatte fælleskomite, s. 104—07).

1918 Løssjord i Norge? (Skand. naturforskermøte, 16. Kra. 1916. Forh. s. 511—17). Også i særtr.

— Norges jordbundsprovinser og klimatiske hovedstrøk (Skand. naturforskermøte. 16. Kra. 1916, Forh., s. 518—26). Også i særtr.

— Statens dyrtidsforanstaltning og nydyrkning av jord. (Norsk landm. bl. *37*, 61—62).

1919 Innstilling fra den av Landbruksdepartementet under 13de september 1918 nedsatte komite til å fremkomme med forslag til plan ang. offentlige foranstaltninger til nydyrkningens fremme (Nydyrkningskomiteen). Ved K. O. Bjørlykke o. a. Kra. 203 s.

— Lærebok i geologi med mineralogi og bergartslære. 3. utg. Kra. 236 s.

— Norske planter. En skoleflora med billeder og med kortfattet plantelære. 5. utg. Kra. XII, 112 s.

— Nydyrkningskomiteens indstilling. (Nationen, nr. 208).

1920 Liten lærebok i mineralogi og geologi for ungdomsskoler, gymnasier og tekniske skoler. 3. opl. Kra. 80 s.

— Norges jordsmon. (Nordmandsforbundet, *13*, 448—55).

— Om stenene og jorden. Kortfattet lærebok i sten- og jordlære, særlig for landbruksskoler. 3. opl. Kra. 136 s.

1921 Jordartsklassifikation; utskillelse og beskrivelse av jordartstyper. (NJF Kongr. Kbh. 1921, s. 161—67, 183).

— Kalk fremfor alt. (Samvirke, *16*, 208—10).

1921 Norske planter. En skoleflora med billeder og med kortfattet plantelære. 6. utg. Kra. XIV, 186 s.

— Om undergrundsbanen og aarsaken til sprækkedannelsen i husene i Kristiania by. II. Kra. 104 s.

— Um steinane og jordi. Stuttmælt lærebok i stein- og jordlære serleg for jordbruksskular. Landsmålsutgåve ved Daniel Danielsen. Kra. 140 s.

— Ønskekvisten. (Norsk landm. bl. *40*, 67—69, 120—22).

1922 Nye undersøkelser om Kristianialeren. (Tekn. ukebl. *40*, 306—07).

— Nyere retninger inden agrogeologien eller jordlæren. (T. norske landbr. *29*, 201—11). Også i særtr.

— Rapport over undersøkelser av 6 lerprøver fra Studenterlunden i Kristiania. (Uttalelse fra den av Arbeidsdepartementet den 18. februar d. å. i anledning av plan for «Undergrundsbanens fremføring til Studenterlunden» nedsatte kommission, s. 29—33).

— Utsikt og plan for Statens jordundersøkelse. Kra. 40 s. (MNLH, *2*, bilag, Jordunders. småskr. 11).

1923 Bidrag til spørsmaalet om nomenklaturen og klassifikationen av jordarter og jordsmon i de nordiske lande. Kbh. 14 s. (Trykt som fortrykk av, men ikke opptatt i NJF. 1923).

— Forsøk paa inddeling av det norske jordsmon. (NJF Kongr., Göteb. 1923, s. 360—70). Også i særtr.

— Statens järnvägars geotekniska kommissions slutbetänkande. Förste byraaingeniör John Olssons imötegaaelse. (Tekn. ukebl. *41*, 344—45).

— Utredning fra Bjørlykke av 8. december 1922 til Corneliussens skrivelse av 11. oktober 1922. (Corneliussen, Einar: Husbeskadigelsene i Kristiania IV. Bilag til Fellesinnlegg nr. 2, s. 32—47).

1924 Die Nomenklatur und Klassifikation der Bodentypen in Norwegen. (Comité internat. de pédol. 4. Comm. no. 13, s. 213—28).

— On soil survey, investigation and mapping in Norway. (Comité internat. de pédol. 5. Comm.: «Cartographie du sol», s. 147—56).

— Typiske norske jordprofiler. (T. norske landbr. *31*, 251—60). Også i særtr.

— En vulkanrest ved Skaar i Greipstad, Vest-Agder. (Norsk geol. t. *7*, 271—80).

— Aarsberetning for Statens jordundersøkelse i 1923. (MNLH, *4*, 104—08).

1925 Bureising på Jæren. (Tidens Tegn, 13. juni).

— Jordprofiler fra Østfold fylke. (NJF *7*, 193—208).

1926 Beretning om Statens jordundersøkelse for årene 1924 og 1925. (MNLH, *6*, 152—60). Også i særtr.

— Lerskred og Osloleren. (Tekn. ukebl. *44*, 353—54).

— Norges landbrukshøiskoles geologiske instituts samlinger 1900—1925. Oslo. 80 s. (Jordunders. småskr. 14).

— De siste lerskred og deres aarsaker. (Tekn. ukebl. *44*, 194—97).

— Surhetsgraden hos norske jordarter. (T. norske landbr. *33*, 70—79). Også i særtr.

— Typische Bodenprofile in Norwegen. (Conf. internat. de pédol. 4, Rome 1924. Actes, s. 467—73). Også i særtr.

1927 Heimstadlæren og skolen. (Skole og samfund, *8*, 1—6).

— Hvordan Ullensaker blev til. Jord og jordsmonn. Plantevekstens innvandring. (I Ullensaker; en bygdebok. Utg. av en komite ved H. Nesten. B. 1, s. 17—53).

— Jordarter og jordprofiler i Norge; en foreløbig oversikt. (MNLH, *7*, 375—420, Jordunders. småskr. 15. 46 s.). Også i særtr.

— Kort oversikt over Møre fylkes geologi. (T. f. Sunnmøre historielag. *16/17* (1925/26), 1—15) — Foredrag.

— Nydyrkningsproblemet. (Ny jord, *14*, 123—26).

1928 The big excursion. (Internat. congr. of soil science. 1, Wash. 1927. Proc. and papers. vol. [5], 144—46). Også i særtr.

— Bodenprofile aus Svalbard. (Soil res. *1*, 96—108).

— Fruktbar jord på forekomster av vulkanske basiske bergarter. (Tidens Tegn, 28. januar).

— Internasjonal jordbunnsforskning og jordbunnskongressen i Washington D. C. 1927. (Naturen, 52, 50—62).

— Jordprofiler fra Møre fylke. (NJF, *10*, 49—67).

— Die klimatischen Bodenregionen in Norwegen. (Internat. congr. of soil science, 1, Wash. 1927. Proc. and papers, vol. [1], s. 285—300).

— Om undergrunnsbanen og årsaken til sprekkedannelsen i husene i Oslo. III. Oslo. 90 s. — Tillegg til «Om undergrunnsbanen III». 31 s.

— Soil types and soil profiles in Norway. (Internat. congr. of soil science, 1, Wash. 1927. Proc. and papers, vol. [4], s. 223—69).

1929 Direktør Joh. L. Hirsch. (I Joh. L. Hirsch. Minneskrift. 1843—1923, s. 12—23).

— Jordbunnsundersøkelserne og våre dyrkningsvidder. (Norsk landm. bl. *48*, 195—96).

— Landbrukshøiskolens grunnleggelse. (I Joh. L. Hirsch. Minneskrift. 1843—1923, s. 36—42).

— Liten skoleflora. Oslo. XII, 130 s.

— Principerne for jordartsstudiet og den agrogeologiske kartlegning i Norge. (NJF Kongr. 4, Helsingf. 1929, s. 314—17).

1930 Die Boden Norwegens. (Die Ernährung der Pflanze, *26*, 291—97).

— Bodenprofile aus Svalbard. (Bodenkundliche Forschungen I, Nr. 2, s. 96—97. Beiheft zu den Mitt. d. internat. Bodenkundl. Gesellsch.).

— Jorden i Ås. Av K. O. Bjørlykke og Aasulv Løddesøl. (MNLH, *10*, 267—352, Jordbunnsbeskr. 26. 80 s.).

— Jordprofiler fra det centrale Norge. (NJF, *11/12*, 449—77).

1931 Om Norges jordsmon. (Naturen, *55*, 370—84, Norsk geol. t. *12*, 89—116).

1932 Evjejorden på Vestlandet. Kan man anvende malet gråsten til gjødsel? (Samvirke, *27*, 282—30).

— Jordforskning og jorddyrkning; geologiske opdagelser. Tre foredrag. Oslo. 48 s. (Norges landbrukshøiskoles høiskolelag. Skr. 2).

— Norske jordarter I. [Kvabben i Østerdalen]. (Samvirke, *27*, 137—38).

— Norske jordarter II. Koppjorden i Solør. (Samvirke, *27*, 153—54).

— Norske jordarter III. Mjelen på Romerike. (Samvirke, *27*, 167—68).

1932 Norske jordarter IV. Mojord eller mjele i Gudbrandsdalen. (Samvirke, *27*, 185—86).

— De norske jordbunnsundersøkelser og deres resultater. (T. norske landbr. *39*, 146—56). Også i særtr.

— Ønskekvisten for svensk videnskapelig domstol. (Samvirke, *27*, 212—13).

1933 Hirschfondet ved Norges landbrukshøiskole; 25-årsberetning. Oslo. (Norges landbrukshøiskoles høiskolelags skr. 3, s. 1—46).

— Jordarter og jordsmon i Østfold fylke. Oslo. 106 s. (Det norske vidensk.-akad. i Oslo. Skr. I, Mat.-naturv. klasse, 1933, nr. 3).

— Jordsmonprofiler av myrjord. (Medd. norske myrselsk. *31*, 71—74, 82—87).

— Kalkingsspørsmålet under ny synsvinkel I. Kalk og mergel. (Samvirke, *28*, 125—26).

— Kalkingsspørsmålet under ny synsvinkel II. Jordens kalktrang. (Samvirke, *28*, 139—40).

— Nydyrkningens planleggelse. (Ny jord, *20*, 19—23).

1934 Jordbunnen på Apelsvoll, Selskapet for Norges Vels beiteforsøksgård. (T. norske landbr. *41*, 53—57).

— Jordbunnen på forsøksgården Holt. (T. norske landbr. *41*, 213—15).

— Jordbunnen på Frogner småbruksskole ved Skien. (Samvirke, *29*, 176—77).

— Jordbunnen på Skansgården landbruksskole pr. Kongsvinger. (Samvirke, *29*, 121—23).

— Jordbunnen på Statens småbrukslærerskole Sem pr. Hvalstad. (Samvirke, *29*, 243, 246).

— Jordbunnen på Storsteigen landbruksskole ved Alvdal st., Østerdalen. (Samvirke, *29*, 75).

— Jordbunnen på Vågønes forsøksgård. (T. norske landbr. *41*, 159—62).

— Norske planter. En skoleflora med billeder og med kortfattet plantelære. 7. utg. Oslo. XIV, 197 s.

— Om kartlegging av jordarter og jordsmonn. (T. norske landbr. *41*, 288—95).

1935 Jordbunnen på Norges forsøks- og landbruksskolegårder. Oslo. 144 s. (Norges landbrukshøiskoles høiskolelag. Skr. 5, Norsk geol. t. *15*, 123—266).

— Litt om «Starane» i Romedal og forekomsten av «bryggestener». (Medd. norske myrselsk. *33*, 166—68).

— Om kartlegging av jordarter og jordsmonn. (NJF Kongr. 5, Kbh. 1935. s. 352—58).

— Om stenene og jordbunden; kortfattet lærebok i sten- og jordbunnslære. 4. rev. oppl. Oslo. 2 bl. 134 s.

— Oversikt over pedologiens nuværende stilling og dens forhold til geologien. Foredrag. (Norsk geol. t. *15*, 312—13).

— Tilbakeblikk på foreningens stiftelse og virksomhet i de forløpne 30 år. Foredrag. (Norsk geol. t. *15*, 308—10).

1936 Litt om fjell og jord i Sande prestegjeld. Aalesund. (Norges landbrukshøiskoles høiskolelag skr. 6, s. 1—16). Særtr. av «Soga um Sande og Rovde». Utg. av Sande og Rovde sogenemnd ved Jakob M. Bjørlykke og Olav Liset. B. 1, s. 11—25.

— Professor Jacob Schetelig. Nekrolog. (Norsk geol. t. *16*, 45—49).

1937 Om et oversiktskart over de løse jordlag i Norge. (Norsk geol. t. *17*, 61—64).

— Om jordbunnen i Pasvikdalen, Statens bureisningsfelt. (T. norske landbr. *44*, 285—303).

1938 Jordbunnen i Murudalen og tilgrensende strøk (Slangen, Heidal). (T. norske landbr. *45*, 40—47).

— Mineralogi og geologi. En liten lærebok for ungdomsskoler, gymnasier og tekniske skoler. 4. rev.oppl. Oslo. 2 bl. 80 s.

1939 Jordsmonnets bedømmelse efter kalkinnhold og type. (T. norske landbr. *46*, 264—79).

1940 Bergmester Thomas Georg Münster. Minnetale. (Norsk geol. t. *19*, 297—99).

— Norske planter. En skoleflora med billeder og med en kortfattet plantelære. 8. utg. Oslo. XIV, 198 s.

— Utsyn over Norges jord og jordsmonn. Med oversiktskarter av jordbunnsforholdene i Norge i to blader: Sør-Norge og Nord-Norge. Målestokk 1 : 2 000 000. Oslo. 235 s. (NGU 156).

1941 Lærebog i geologi med mineralogi og bergartslære. 4. utg. ved Harald Bjørlykke. Oslo. 263 s.

1942 Norges jord og jordsmonn. (Norsk jord, *2*, nr. 11, s. 7—23).

— Norges jordbunnsprovinser. (Norsk jord, *2*, nr. 21, s. 9—10).

— Norges naturlige jordbruksområder. (Norsk jord, *2*, nr. 24, s. 6, 18).

1943 Norges klimatiske jordbunnsregioner; klimaets innflytelse på jordsmonnet. (Norsk jord, *3*, nr. 8, s. 5, 19).

— Oversiktskart over jordbunnsforholdene i Norge. (Norsk jord, *3*, nr. 11, s. 8).

— Trekk fra mitt samvær med bondehøvdingen Joh. L. Hirsch; til minne om 100 årsdagen for hans fødsel 31. desember 1943. (Norsk jord, *3*, nr. 24, s. 10—11, 19).

1946 Om stenene og jordbunden. 5. rev. oppl. Rev. av Harald Bjørlykke. Oslo. 2 bl. 137 s.

1952 Norske planter. Skoleflora med bilder og en kortfattet plantelære. 9. utg. Oslo. XVI, 198 s.

1956 Norske planter. Skoleflora med 363 illustrasjoner og en kortfattet plantelære. 10. utg. Oslo. XVI, 198 s.

1958 Norske planter. Skoleflora med 363 illustrasjoner og en kortfattet plantelære. 11. utg. Oslo. XVI, 198 s.

NY LITTERATUR

Mineralogy, Concepts, Descriptions, Determinations.
L. G. Berry and Brian Mason, illustrasjoner ved R. Hayward.
W. H. Freeman and Company, San Francisco, Calif., 1959.
612 sider, 265 illustrasjoner, pris $ 8.75.

Boken er no. 8 i serien «A series of books in geology», redigert av J. Gilluly og A. O. Woodford.

Bokens formål er å fylle kravene til et «undergraduate» kurs i mineralogi. Den passer utmerket som referensebok ved mineralogiundervisningen ved norske universiteter.

Bokens første del inneholder: Innledning (1—11), Krystallografi (12—149), Mineralkjemi (150—183), Mineralfysikk (184—209), Mineralgenese (210—250), Beskrivende mineralogi (251—270), Mineralogisk systematikk (271—275).

I denne delen er det særlig kapitlene mineralkjemi og mineralgenese som hever boken over de fleste andre av denne typen. Mineralkjemien omhandler tolking av analyser, komponenter og faser, krystallkjemiske prinsipper, kjemiske bindinger og ione størrelser, solidsolution og polymorfisme.

Kapitlet over mineralgenese legger hovedvekten på sammenligninger mellom observasjoner og fysikalsk kjemiske og eksperimentelle data. Dette kapitlet er blitt en kortfattet geokjemi.

Annen del (276—568) er mineralbeskrivelse. I alt er noen hundre mineraler behandlet hvoriblandt alle alminnelig forekommende. De enkelte mineralene er alle beskrevet etter samme skjema uten overflødig tekst. En mengde fotografier og diagrammer anskueliggjør teksten på en utmerket måte.

Tredje del (569—597) inneholder identifikasjons-tabeller hvor følgende data er gitt: navn og formel, farge, egenvekt, hardhet, krystallsystem og vanlig utvikling, spalteretninger, «smeltbarhet».

Tabellene er nyttige for visuell mineralidentifikasjon, men som forfatterne sier: den beste nøkkel til mineral-identifisering er «Be smart».

Det synes å være en svakhet at optiske konstanter ikke er gitt.

Elementenes atom- og ioneradier er gitt i et appendix. De siste er «Ahrens radier» og det ville være en fordel om også «Goldschmidt's radier» var gitt.

Til slutt noen ord om illustrasjonene. De er som oftest vakre og dekker teksten på en utmerket måte. Fotografiene synes vesentlig å være originale, men en hel del av diagrammene er utvilsomt kopiert uten at referenser er gitt. Den tegnede figurteksten og tall er tydelig, men bærer for meget preg av frihåndstegning og det burde vært valgt andre typer.

Boken kan anbefales til alminnelig mineralogi- og krystallografi-undervisning.

Knut S. Heier.

Steiner i farger. Av IVAR OFTEDAL.
Aschehoug, Oslo 1960. 47 tekstsider, 64 fargeplansjer. Pris innbundet kr. 19,50.

I den nordiske serie «Naturen i farger» er man nå, via atskillig zoologi og botanikk, kommet frem til geologi.

«Steiner i farger» innledes med 64 sider fargeplansjer av de vanligste mineraler og bergarter. Det er også blitt plass til tre meteoritter. Fargeplansjene er de samme som i de tilsvarende utgaver i de andre skandinaviske land. Det er jo nettopp dette samarbeid som gjør det mulig å gi ut en bok som «Steiner i farger» her i Norge til en overkommelig pris. Fotograferingen er utført i Stockholm. Det er brukt meget svensk materiale, men en finner også en rekke norske stuffer gjengitt. Fargegjengivelsen er stort sett meget vellykket, og plansjene forteller oss atskillig om de avbildete steiner.

I motsetning til fargeplansjene er tekstdelen, ifølge forordet, et helt selvstendig arbeid av forfatteren. Teksten gir en kort beskrivelse av de avbildete mineraler og bergarter. Den følger, likesom fargeplansjene, den sedvanlige inndeling. Mineralene er ordnet i hovedgrupper etter kjemien, og bergartene er inndelt i eruptive, sedimentære og metamorfe bergarter. Videre følger meteoritter, bestemmelsesnøkler for noen mineraler og bergarter, navneregister og sakregister. Det hele er greitt og oversiktlig ordnet og fremstilt.

Den eneste tekstillustrasjon er et helsides kart over Norges fjellgrunn. Det er svært forenklet, f.eks. er våre devonavsetninger ikke avmerket. Men heller ikke av selve tekstdelen fremgår det at vi har devon i Norge. På den annen side gjengir plansjen s. 49 et vakkert konglomerat fra Hornelens devon. Som kjent er våre devonavsetninger både bergartsmessig og landskapsmessig meget iøynefallende.

Jeg leste for en tid tilbake anmeldelsen i Geologiska Föreningens Förhandlingar av den tilsvarende svenske utgaven, P. H. Lundegårdhs «Stenar i färg». Etter den positive kritikk, både av fargeplansjer og tekst, var det med atskillig forventning jeg åpnet den norske utgaven. Et hovedinntrykk er at tekstdelen er noe knapp i forhold til fargeplansjene. Når beskrivelsen av 64 plansjer med tilsammen 267 bilder blir presset sammen på 47 tekstsider, blir det plass til lite mer enn en oppramsing av de viktigste data. Jeg har ikke sett den svenske utgaven, men ifølge anmeldelsen har den 127 tekstsider, eller nesten tre ganger så lang tekst som den norske. En slik tekstlengde gir utvilsomt en ganske annen mulighet til å gi teksten liv og til å formidle en geologisk forståelse. I den svenske utgaven er det f.eks. blitt plass til svart-hvitt bilder i teksten.

Vår populærvitenskapelige geologiske litteratur er ganske mager, og «Steiner i farger» er et viktig og velkomment tilskudd. Vi har her en bok som kan anbefales interesserte som søker opplysninger om det de kan finne i fjellgrunnen. Med det enestående opplegg som fargeplansjene gir, ville det dog være meget ønskelig at tekstdelen ved en eventuell ny utgave ble utvidet.

Ivar Hernes.

NORSK GEOLOGISK FORENING

Møte nr. 388 torsdag 31. mars 1960 kl. 19

i Drammensveien 78, Oslo.

Tilstede 47 medlemmer og 13 gjester. Formannen ledet møtet. Referat fra møte nr. 387 ble lest opp og godkjent.

Professor dr. *Anders Kvale* holdt foredrag om «Norske jordskjelv og deres forhold til tektonikk og postglasial landhevning.»

I ordskiftet etter foredraget deltok: J. A. Dons, K. Strøm, T. Strand, T. Barth, O. Holtedahl, I. Rosenqvist, B. Andersen, N. Spjeldnæs og foredragsholderen.

Medlemmene ble gjort kjent med at de var invitert til Norsk Bergindustriforenings møte 28/5, hvor direktør H. Bjørlykke holdt foredrag om Praktisk-geologiske undersøkelser ved NGU.

GEOLOGNYTT

Norges geologiske undersøkelse.

Statsgeolog II Fredrik Hagemann ble beskikket som statsgeolog I pr. 1. desember 1959.

Vitensk. assistent I Ole-Kristoffer Ihle ble ansatt som statsgeolog II pr. 1. desember 1959. Han fratrådte stillingen 1. august 1960.

Cand. real. Audun Hjelle ble ansatt som vitensk. assistent I pr. 7. desember 1959 og som statsgeolog II pr. 1. januar 1960.

Statsgeolog II Thor Siggerud fratrådte stillingen pr. 1. januar 1960.

Midlertidig statsgeolog II dr. philos. Paul H. Reitan ble ansatt i midlertidig stilling som statsgeolog I pr. 1. januar 1960. Han fratrådte stillingen 1. september 1960.

Midlertidig vitensk. assistent I Christian Dick Thorkildsen ble ansattt som vitensk. assistent I pr. 1. februar 1960.

Cand. real. Fredrik Christian Wolff ble ansatt som vitensk. assistent I pr. 16. februar 1960 og som statsgeolog II pr. 1. august 1960.

Cand. real. Magne Gustavson er blitt ansatt som vitensk. assistent I. Han tiltrer stillingen 1. januar 1961.

Universitetet i Oslo.

Institutt for geologi.

Professor Olaf Holtedahl ble høsten 1960 utnevnt til æresdoktor ved Stockholms Universitet.

Professor Trygve Strand avløser professor Ivar Oftedal som instituttets bestyrer 1. januar 1961.

Professor Ivar Oftedal har forskningstermin i vårsemesteret 1961.

Følgende gjestende forskere har arbeidet ved instituttet i kortere eller lengere tid:

Dr. Isabel C. Cookson, Melbourne. (Avd. D). Paleobotanikk.

Professor J. H. McDonald Whitaker, Leicester. (Avd. C). Stratigrafi i Oslofeltet.

Gordon C. Grender, Ph. D., Pennsylvania. (Avd. A). Sedimentpetrografi i sparagmittformasjonen.

Mineralogisk-geologisk museum.

Professor T. F. W. Barth er blitt tildelt the Roebling medal. Han er også blitt utnevnt til æresdoktor ved universitetet i Nancy.

Førstekonservator Johannes A. Dons ble i august 1960 utnevnt til generalsekretær for den XXI Internasjonale Geologiske Kongress.

Dr. R. MORTON sluttet som vitensk. assistent 1. juli 1960.

Cand. mag. JOHAN NATEASTAD ble ansatt som vitensk. assistent fra 1. juli 1960.

Dr. R. H. FILBY er for en bevilgning fra Norges almenvitenskapelige forskningsråd ansatt som forskningsstipendiat for å studere fordelingen av elementer mellom mineraler i likevekt, ved hjelp av radiokjemiske metoder.

Følgende gjestende forskere arbeider ved museet:

Professor E. W. SIMPSON, South Africa.
Dr. G. K. CZAMANSKE, U.S.A.
SCOTT B. SMITHSON, M.A., U.S.A.
Miss M. L. BUSÉ, M.Sc., Guatemala.
T. G. ELDER, B.Sc., Great Britain.

Paleontologisk museum.

Konservator HALVOR ROSENDAHL fratrådte stillingen 30. april 1960.

Dr. philos. NILS SPJELDNÆS tiltrådte stillingen som konservator 1. mai 1960.

Vitensk. assistent NATASCHA HEINTZ fratrådte stillingen 30. september 1960.

Stud. real. FRANK NIKOLAISEN er ansatt som museumsstipendiat for annet halvår 1960.

Norsk polarinstitutt.

Cand. real. NATASCHA HEINTZ er ansatt som konsulent fra 1. okt. 1960.

Universitetet i Bergen.

Geologisk institutt.

Førstekonservator HANS HOLTEDAHL ble beskikket som dosent fra 1. januar 1960.

Amanuensis I IVAR HERNES ble ansatt som førstekonservator fra 1. juli 1960.

Cand. real. INGE BRYHNI tiltrådte som midlertidig vitensk. assistent 1. juli 1960.

Jordskjelvstasjonen.

Ved hjelp av midler fra Norges almenvitenskapelige forskningsråd ble der sommeren 1960 opprettet en jordskjelvstasjon i Tromsø Museums nybygg. Den har en 3-komponent Benioff seismograf, og ble satt i drift 15. september 1960. Opprettelsen og driften av stasjonen er et samarbeid mellom Jordskjelvstasjonen i Bergen og Tromsø Museum.

For å studere forholdet mellom bølgegangen på kysten og uroen i jordbunnen (mikroseismikken) har Jordskjelvstasjonen, med støtte av L. Meltzers Høyskolefond, montert et måleinstrument for havbølger ved Alnes Fyr (vest for Ålesund).

Norges tekniske høgskole.

Geologisk institutt.

Cand. real. MAGNE GUSTAVSON fratrer stillingen som vitensk. assistent 31. desember 1960.

Instituttet flyttet i løpet av månedene juni-september fra sine gamle lokaler inn i sin nye bygning, en 4 etasjes blokk. Offisiell overlevering vil finne sted senere.

Geofysisk malmleting.

Midlertidig geolog II HANS-PETER GEIS sluttet ved Geofysisk malmleting 13. april 1960 for å overta en stilling ved Rødsand Gruber.

Geolog TEK HONG TAN, som siden 23. april 1959 har vært ansatt som vikar i geofysiker II stilling, vil fra 1. januar 1961 gå inn i den ledige stilling etter H. P. Geis.

Doktorgrader.

Følgende er av Det akademiske kollegium ved Universitetet i Oslo kreert til *doctor philosophiae:*

KNUT S. HEIER. Avhandling: «Petrology and geochemistry of high-grade metamorphic and igneous rocks on Langøy, Northern Norway.»

DWIGHT F. CROWDER. Avhandling: «Granitization, migmatization, and fusion in the northern Entiat Mountains, Washington.»

BJØRN GROTHAUG ANDERSEN. Avhandling: «Sørlandet i sen- og postglacial tid.»

Eksamener.

Ved Universitetet i Oslo er embetseksamen med mineralogi-petrografi som hovedfag fullført av:

SVEINUNG BERGSTØL. Hovedoppgave: «En petrografisk og mineralogisk undersøkelse av bergartene rundt Fensfeltet, med hovedvekt på gangbergartene.»

JENS HYSINGJORD. Hovedoppgave: «En petrografisk beskrivelse av metamorfe og eruptive bergarter på Stjernøy, Vest-Finnmark.

Ved Universitetet i Bergen er embetseksamen med fysisk geografi som hovedfag fullført i vårsemesteret 1960 av:

ATLE SINDRE. Hovedoppgave: «En undersøkelse av observerte gangtider i Bergen for jordskjelvfasene P, PP, PPP, PS, PPS, PKP, PKS, PcP og PcS.»

ANDERS SØRNES: Hovedoppgave: «En undersøkelse av observerte gangtider i Bergen for jordskjelvfasene S, ScS, SKS, SKKS og SS.»

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à jour november 1960,
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Busé, M. L., Miss. 1a Av. 6—18 Zona 14, Guatemala City, Guatemala. (1960).
Bølviken, Bjørn, ingeniør. Statens Råstofflaboratorium, Postboks 1078, Trondheim. (1958).
*Callisen, Karen, dr. Mineralogisk og Geologisk Museum, Østervoldgade 7, København K, Danmark. (1917).
*Carstens, Harald, geolog. Saxenborg, Trondheim. (1949).
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*Danielsen, Anders, konservator. Botanisk museum, Bergen. (1949).
*Davidson, Charles F., professor, Department of Geology, The University, St. Andrews, Skotland. (1960).
*Devore, George W., dr. Dept. of Geology, University, Chicago 37, Ill. ,U.S.A. (1948).
*Dietrich, R. V., professor. Dept. of Geological Sciences, Virginia Polytechnic Institute, Blacksburg, Virginia, U.S.A. (1959).
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Dybdahl, Ivar, bergingeniør. A/S Titania, Hauge i Dalane. (1958).
*Eckermann, Harry von, professor. Edeby pr. Ripsa, Sverige. (1937).

*Edelman, Nils, dr. Bolidens Gruv AB., Boliden, Sverige. (1956).
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Elder, T. G. Geologisk Museum, Sarsgt. 1, Oslo. (1960).
*Elders, Wilfred Allan, B. Sc. Dept. of Geology, Kings College, Newcastle, England. (1958).
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Landmark, Einar, direktør. Tidemandsgt. 14, Oslo. (1941).
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Løkås, Bjørge, lektor. Harry Borthensvei 8, Østmarkneset, Trondheim. (1960).

Løvaas, Gunnar, bergingeniør. Skorovas Gruber, Skorovatn p. å. (1949).

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Norin, Erik, professor. Mineralogisk-geologiska Institution, Uppsala, Sverige. (1947).
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Ormestad, Solveig Bonde, cand. jur. Bernhard Herresvei 19, Smestad, Oslo. (1959).
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Pehkonen, Eero, geolog. Geologiska Forskningsanstalten i Finnland, Boulevardgt. 29, Helsingfors, Finnland. (1955).
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Prost, André, dr. Laboratoire de Geologie du S. P. C. N., 12 Rue Cuvier, Paris 5e, Frankrike. (1959).
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Semb, Gunnar, forsøksleder. Norges landbrukshøgskole, Vollebekk. (1941).
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